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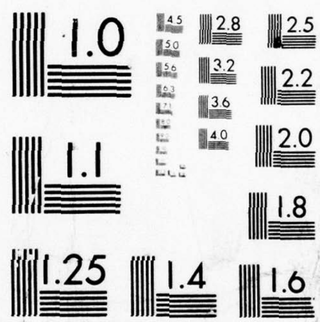


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# AVIONICS COST DEVELOPMENT FOR ALTERNATIVES OF SELECTED AIR TRAFFIC CONTROL SYSTEMS

FINAL REPORT

S. H. Kowalski

October 1977





PREPARED FOR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Office of Systems Engineering Management
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This report presents the results of the cost analysis of avionics required in support of the Upgraded Third Generation Air Traffic Control developments. The systems considered were recommended for evaluation by the Office of Systems Engineering Management of the FAA.

The costs of avionics were developed with the aid of a pricing model to provide comparative evaluations based on uniform parametric data varying only in system-peculiar descriptors.

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## SUMMARY

ARINC Research Corporation is assisting the Federal Aviation Administration under Contract DOT-FA76WA-3788, in the development and evaluation of technical and cost factors that will affect the FAA policy regarding the Separation Assurance System as a national standard. One of the contract efforts was to develop avionics costs required for an assessment of various alternatives to improving communications and surveillance for aircraft separation services in the national airspace system.

This report was prepared in response to the Department of Transportation's review of Upgraded Third Generation Air Traffic Control System Developments; it reflectes the concepts and system designs advocated by the organization responsible for the evaluation and assessment of the UG3RD. The systems considered in the study were recommended for evaluation by the Office of System Engineering Management of the FAA.

The concepts subjected to evaluation range from systems currently in use for air traffic control (ATC) to new developments proposed either to replace or to enhance present ATC operations. The development of avionics costs could have been limited to concepts identified as new or enhancements since equipment cost data for these concepts are not available from existing price lists. ARINC Research Corporation chose to develop costs on all alternatives to provide credibility in the results by uniformly cost estimating each item of avionics and permitting comparison of the study results with nationally advertised manufacturers' prices. The tool chosen for cost estimating was the RCA-developed Program Review of Information for Costing and Evaluation (PRICE) pricing model because of its wide acceptance by government agencies and the uniformity of the parametric data required in describing the equipment to be evaluated.

Adaptation of the pricing model to avionics cost estimating required extensive sensitivity analyses of the effect of each of the 40 data parameters used as inputs to the model. A data base was compiled on each potential manufacturer of avionics and the model tailored to reflect the physical and economic characterization of each manufacturer. Detailed data on existing avionics considered critical by the model for tailoring to a specific manufacturer were obtained by physical measurements at the manufacturer's plant and through interviews with the manufacturer's representatives. These efforts permitted the preparation of parametric data that resulted in almost exact

replication of the costs of subassemblies and systems when processed by the pricing model for existing systems. The parametric data compiled were then applied to new concepts by associating similar subassemblies with existing modules and holding the economic parameters of the model constant for any single manufacturer.

The results of the study evaluation are presented in Table S-1. The costs shown are for the equipment identified and represent the major modules of system implementation. The costs are developed for the air carriers, which purchase equipment in large quantities and therefore enjoy quantity discounts, as well as for the single-aircraft or small fleet owners, who must pay the distributor markups. The classes of avionics evaluated in the study were those designed to ARINC specifications for high-performance aircraft and those designed to the less stringent requirements of the general aviation community intended for installation in single-engine and twin-engine low-performance aircraft.

Implementation of any of the alternatives requires complementary equipments, such as antennas, controls, and displays, not identified in Table S-1. The cost of equipment acquisition for each concept suitable for airborne operation of a single system per aircraft is presented in Table S-2. The costs of complementary equipment were either developed in this study or obtained from manufacturers' price lists for the appropriate class of users.

*Table S-1.* ACQUISITION COST OF AVIONICS

| Equipment | Cost (in 1976 dollars) by User Category | | |
|---|---|---|---|
| | Air Carrier | High-Performance General Aviation | Low-Performance General Aviation |
| ATCRBS Transponder | 3975 | 5169 | 612 |
| DABS Transponder | 5212 | 6776 | 1352 |
| SAB Transponder | 4176 | 5429 | 784 |
| VHF Transceiver | 2500 | 3250 | 1254 |
| VHF Data Modem | 2845 | 3699 | 1240 |
| ATC Display | 1576 | 2049 | 486 |
| IPC/PWI Display | 2198 | 2857 | 1114 |
| Auto-Tune Control | 299 | 389 | N/A |
| ACAS Electronics | 3979 | 5173 | 1118 |

Table S-2. ACQUISITION COST OF SYSTEMS - SINGLE SYSTEM PER AIRCRAFT

| System | Cost (in 1976 dollars) by User Category | | |
|---|---|---|---|
| | Air Carrier | High-Performance General Aviation | Low-Performance General Aviation |
| ATCRBS | 4554 | 5760 | 625 |
| DABS/IPC | 8052 | 10299 | 1365 |
| SAB | 4755 | 6020 | 797 |
| VHF Voice | 3196 | 4006 | 1270 |
| VHF Data Link | 4772 | 6055 | 1756 |
| VHF D/L + IPC | 7269 | 9301 | 2870 |
| ACAS | 5197 | 6415 | 1144 |

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*CHAPTER ONE*

# INTRODUCTION

## 1.1 BACKGROUND

The Federal Aviation Administration (FAA) recognizes the direct correlation between the growing aircraft population and the ever-increasing difficulty in providing separation assurance and collision avoidance through the current Air Traffic Control (ATC) system. Efforts to develop an improved national standard to provide separation assurance have resulted in the upgraded third-generation air traffic control system. Programs such as the Selective Address Beacon (SAB), the improved Air Traffic Control Radar Beacon System (ATCRBS), Discrete Address Beacon System (DABS), VHF data link, and Airborne Collision Avoidance System (ACAS) are being subjected to exhaustive investigations to determine their applicability to future ATC plans and operations. The MITRE/METREK Corporation has been evaluating the economics of each system's implementation and has developed the expected costs of the ground equipments required for introducing each system.

The Office of System Engineering Management (OSEM) of the FAA has engaged ARINC Research Corporation, under Contract DOT FA76WA-3788, to perform a series of investigations and to provide separate reports on the findings associated with each of these investigations. The contract directs ARINC Research Corporation to analyze and develop the technical, operational, and economic feasibility of implementing certain surveillance and separation assurance concepts in the expected aircraft population of the 1980s and beyond. The system investigations to be performed span the range from comprehensive, long-term solutions to partial, short-term solutions for improving surveillance and collision avoidance.

## 1.2 CONTRACT SCOPE AND OBJECTIVES

The overall investigative effort involves many of the alternative ideas for upgrading the present Air Traffic Control system and entails the development and analysis of performance and cost factors in the following five task areas:

Task I - Avionics Alternatives for Selected ATC System Developments

Task II - Selective Address Beacon System

Task III - VHF Data Link

Task IV - DABS/IPC Impact on Air Carriers

Task V - ARINC Interfaces with FAA Communications Modernization Program

This report documents the results of Task I.

## 1.3 PROJECT OVERVIEW

The objective of Task I is to develop an independent assessment of the cost of avionics required to implement the systems defined by MITRE/METREK in their report on the cost of various alternatives (Reference 1). To meet this objective, it has been necessary to analyze the concepts defined by MITRE/METREK and develop the necessary designs in sufficient detail to permit cost estimating by application of either known conventional methods or commercially available pricing models. ARINC Research was directed by contract to choose the latter alternative. This report presents the cost estimating methodology, the constraints applied to ensure uniformity in the development of avionics costs for each system, and the results of the application of the pricing model.

## 1.4 ORGANIZATION OF THE REPORT

The nine chapters of this report address the techniques used in cost-estimating system designs of the concepts evaluated, and present the results obtained from application of the pricing model.

Chapter Two identifies the pricing model used in the study and provides a discussion of the parametric data required for model execution.

Chapter Three describes the overall approach to developing uniform cost estimates, as well as the assumptions and constraints employed.

Chapters Four through Eight are devoted to the evaluation of the systems and the costs of the avionics required for implementing each system. Each system is treated in a separate chapter because of the variability of data sources used in the analysis and the uniqueness of each concept evaluated.

Chapter Nine summarizes the results of the study and describes the uniform approach and application of the cost estimating technique used throughout the evaluation.

Appendix A presents a listing of the input parameters used by the RCA PRICE model. Appendix B presents a list of references used in this report.

*CHAPTER TWO*

# PRICING METHODOLOGY AND THE PRICE MODEL

The equipment costs developed in this study will provide the basis for the economic comparison of various concepts intended to improve separation assurance and surveillance in the next generation of ATC systems. Careful development of these data is an essential step in the overall analysis of the alternatives. Although several cost estimating techniques are available, the need for relative comparison, as well as absolute costs, dictated that the method used be capable of identifying sufficient similarity in approach to provide confidence that the results were based on the same population of data. A parametrically controlled computer-based method appears to provide this level of confidence and comparison for relative evaluation; the method need only be proven accurate for absolute cost of equipment. This chapter addresses the method used in the study and identifies the model chosen for cost estimating and evaluation.

## 2.1 COST ESTIMATING METHOD

The model chosen for equipment pricing, the RCA Programmed Review of Information for Costing and Evaluation (PRICE), requires a set of parametric data inputs that properly define the module, or system, to be estimated. The model was chosen because of its wide acceptance by branches of the Federal Government as a computer-based pricing model. Of the many input parameters required, the most critical cost-driving ones are the item weight, volume, structural-electronic division, manufacturing complexities, and markups for overhead, G&A, and profit. Since manufacturing complexities vary among manufacturers in different fields (e.g., avionics or fixed ground equipment) and even among manufacturers within a field (e.g., avionics for ARINC class or general-aviation class equipments), a detailed characterization of each manufacturer expected to be in production of avionic equipment is necessary.

ARINC Research has established the manufacturing complexities of several key manufacturers of avionics by thoroughly reviewing existing avionics, making visits and collecting data at various avionics plants, and performing frequent exercises of the PRICE model to establish the sensitivities of the parametric data. To ensure accuracy in existing equipment characterization, actual measurements of size and weight were performed on all modules defining a specific item of avionics, and the process was repeated on multiple types of avionics to ensure a statistically sufficient sample.

The results were compiled and stored in ARINC Research data files and were used in estimating the cost of the avionics defined by this study.

## 2.2 THE PRICE MODEL

PRICE is an RCA-developed parametric cost-modeling technique. It is a computerized method that estimates development and production costs on the basis of physical and economic descriptors of systems evaluated. It applies the principle that all estimates involve comparative evaluations of new requirements to analogous histories with empirical data bases. PRICE efficiently stores, retrieves, and uses historical information. Effective use of empirical data allows classifying new ideas by relating them to past similar occurrences. The method provides the means of reducing empirical data to a few principal variables that can be adjusted for the specific system economic and technological differences.

### 2.2.1 Model Input Data

The model requires up to 40 parametric data inputs describing the physical and economic characteristics of the system or subassembly to be evaluated. When operated in the subassembly mode, the model requires similar inputs for all subassemblies and provides the means for final test and integration of the system. In general, the latter mode was employed for all cost estimating exercises performed in this study.

The physical descriptors included key features such as weight of structure and electronics, packaging densities, volumes, quantities to be produced, manufacturing complexities, and design requirements. Since the model is structured to provide a cost-per-pound based on densities and complexities, an accurate determination of the probable weight and volume of the subassembly being evaluated is mandatory.

The economic descriptors include features such as year of production, escalation rates, engineering schedules, production schedules, and management required during development and production. Careful selection of schedules is necessary because the final costs developed by the model are affected by the complexity of a product and the time allowed for development and production of the product. Other economic considerations, such as management, tooling, or test equipment, have been normalized to the RCA data bank and are altered through sensitivity analyses and adaptation to specific manufacturers.

The key input parameters are listed in Table 2-1 in the format used throughout the study. Abbreviations and acronyms used are defined to provide an insight into the parametric data employed by the model. A complete listing of input parameters used by the model is presented in Appendix A.

### 2.2.2 Model Output Data

The RCA PRICE model performs a series of evaluations based on the input parametric data and provides costs as a function of the elements associated with engineering and manufacturing for both development and production of a

*Table 2-1.* KEY PRICE PHYSICAL AND ECONOMIC DESCRIPTORS

| DESCRIPTOR ACRONYM OR ABBREVIATION | DESCRIPTION |
|---|---|
| QTY | Total Quantity to be produced |
| WT | Weight of assembly (subassembly) in pounds |
| VOL | Volume of assembly (subassembly) in cubic feet |
| WS | Weight of structure (nonelectronic) of assembly in pounds |
| MCPLXS | Manufacturing complexity for structure |
| NEWST | Percent of new design required for structure |
| MCPLXE | Manufacturing complexity for electronics |
| NEWEL | Percetn of new design required for electronics |
| CMPNTS | Number of electronic components |
| ECMPLX | Engineering complexity of assembly (subassembly) |
| PRMTH | Production period in months |
| LCURVE | Production learning curve |
| ECNE | Engineering change orders for electronics, in percent |
| ECNS | Engineering change orders for structure, in percent |
| YEAR | Year of technology (usual start of design/production) |
| ESC | Escalation rate in percent |
| PROJCT | Degree of project management support during engineering |
| DATA | Degree of data requirements |
| TLGTST | Degree of special tools and test equipment required for development |
| PLTFM | Factor for reliability testing, specification severity |
| SYSTEM | Degree of system engineering required |
| PPROJ | Degree of project management support during production |
| PDATA | Degree of data required during production |
| PTLGTS | Degree of special tools and test equipment required for production |

system or subassembly. Engineering costs include the cost of drafting, design, system management, project management, and data documentation required during system development and production. The costs are presented for the entire production quantity and development/production period on the basis of the data input parameter set, and include the effect of inflation (escalation). Manufacturing is concerned primarily with the production of a system, but it also encompasses costs for prototype development and special tooling/test equipment that might be required during development. As in the case of engineering, the output costs are presented for the entire production quantity with appropriate escalation.

During program execution, the model performs frequent calculations of schedules, densities, and other key input parameters, and compares the results with historical data in the RCA data banks. Abnormal inputs, such as insufficient development periods, are flagged and brought to the attention of the operator.

The output data sheet contains all the information used as the parametric input to the model; it also provides key parameters used in the computer evaluation for comparison with empirical data sets and mathematical patterns from the RCA library to monitor the reasonableness of the results. Finally, the output data sheet provides the expected cost estimated by the program, bounded by approximately two-sigma level-of-confidence costs. The confidence intervals, although available from the model results, are omitted from this study, in order to retain similarity to other economic analysis reports used in the evaluation of future ATC alternatives. A copy of a typical model output data sheet is provided in Appendix A.

# CHAPTER THREE

## STUDY APPROACH

This report is concerned with the economic analysis of the ATC alternatives identified in the MITRE/METREK report (Reference 1), and this chapter addresses the approach used in these analyses. The development of accurate costs of avionics ranging from production units through prototype models to conceptual designs poses a number of problems, including the following:

- Establishing a Common Basis for Evaluation. The system concepts are in different stages of evolution and employ different technology levels. Evaluating criteria that take these differences into account and are equitable for each alternative are needed to ensure that the study results will provide an objective evaluation of each concept.

- Obtaining Accurate and Comparable Cost and Design Data. The designs of the alternatives have been presented in functional block formats to identify operational capabilities. These designs must be converted to electrical and structual details suitable for development of the pricing model. Therefore, it has been necessary to convert the functional block diagrams into readily identifiable operational modules based on similar equipment in existing avionics, or to design new modules on the basis of similar efforts in associated studies.

The general approach followed by ARINC Research Corporation in resolving these problems and obtaining the comparative economic evaluation of the alternatives is described in this chapter.

### 3.1 UNIFORM GROUND RULES USED IN THE STUDY

ARINC Research Corporation has developed costs of avionics in conjunction with other studies for the FAA (Contract DOT FA74WA-3506, references 2 and 3) used in an overall economic evaluation to establish the relative costs of concept implementation. To maintain uniformity in the economic evaluation, the same set of ground rules used in these past studies has been adhered to in this report. The exceptions to these rules are as follows:

- Classes of Equipments - The classes of equipments are limited to those intended for air carriers and other high-performance aircraft, as well as a general-aviation version intended for low-performance aircraft.

- Technology Levels of the Production Designs - Consistent with the present manufacturers' practices in a limited (nonmandatory) market, LSI circuitry is not anticipated, with the majority of electronic digital systems making maximum use of MSI circuits, ICs, and discrete components.

- Quantities Produced per Manufacturer - It is assumed that there will be multiple manufacturers of each class of equipment and that each manufacturer will produce sufficient quantities to complete the production learning curve and amortize development and start-up costs. It is assumed that each manufacturer of high-performance systems will produce at least 3000 units over a three-year period. The general-aviation manufacturer is expected to maintain present production rates for similar equipment. Therefore, this study is based on production of 3000 units over a three-year period.

- Computation of Equipment Costs to the Users - Current manufacturers' practices of establishing factory selling price and user list price are followed in this study. Manufacturers of high-performance equipment are assumed to increase the factory cost of avionics by 20 percent for G&A and 15 percent for profit, compounded to 38 percent over factory cost in establishing the factory selling price. This is the cost to distributors and large-quantity buyers, such as the air carriers. An additional 30 percent markup by distributors establishes the expected selling price to private owners of high-performance aircraft.

  For general-aviation manufacturers, a 67 percent markup over factory cost is assumed to cover overhead, G&A, and profit in establishing the factory selling price. The current practice of 100 percent markup over factory selling price for distributors is also reflected in the study in determing the selling price to the GA user.

All equipment costs in this study are in constant 1976 dollars. Amortization of all development is assumed over the entire production quantity.

## 3.2 SYSTEM DATA ELEMENTS

On the basis of the input data requirements specified by the PRICE model, detailed system performance data and physical configurations were developed for each of the alternatives to be evaluated. These data included physical descriptions and electrical characteristics for both the air carrier and general-aviation classes of avionics. The basic descriptors were obtained from the MITRE/METREK study of alternatives. Specific physical and electrical characteristics were obtained either from studies of each new alternative (e.g., Cost Analysis of Airborne Collision Avoidance System Concepts, Reference 2) or from published manufacturers' data on modules and subassemblies that were considered adaptable to the alternatives' design. ARINC Research interpretations (presented in subsequent chapters) of the alternatives' functional descriptions were converted to data sets for evaluation by the RCA PRICE model.

### 3.3 ADAPTABILITY OF THE PRICING MODEL

PRICE is a parametric model developed to reflect the trends and production techniques of specific manufacturers. The proper operation of the model requires that the peculiarities of a manufacturer be established and a data base developed. Since this study is concerned with the production of avionics for both air carrier and general-aviation aircraft, it was necessary to develop the required data base of manufacturers engaged in the manufacture of the appropriate class of avionics.

Two leading manufacturers of ARINC specification avionics and two manufacturers of general-aviation avionics were investigated and categorized in a language common to the PRICE model. A number of sensitivity analyses were performed on existing avionics to duplicate the cost of production of the avionics based on both published cost data and information provided by manufacturers. Where possible, actual measurements of size and weight of existing subassemblies were taken at the manufacturers' plants and the results applied to the pricing model to determine the key parameters affecting the model. A statistically sufficient sample of data was developed for each manufacturer to establish confidence in the results obtained from the model.

This report presents the cost estimates developed for new systems considered in the alternatives evaluation. It also presents the PRICE-developed costs of existing avionics that are a part of the alternatives evaluation. The latter exercise is included to provide a comparison of the parametric data on similar assemblies and enhance the credibility of results of new concepts as developed by the pricing model.

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CHAPTER FOUR

# AIR TRAFFIC CONTROL RADAR BEACON SYSTEM (ATCRBS) AVIONICS

Since the early 1960s, civil air traffic control has been enhanced by use of the secondary surveillance radar (SSR), which has provided accurate range, identity, and altitude information on equipped aircraft in the national air space. The avionics required in support of the ATCRBS concept are the airborne transponder operating at 1030 MHz and 1090 MHz and the associated control panel and antenna. Many models of the transponder have been introduced, and these properly reflect the technological advancements made since the introduction of ATCRBS. New technology has provided a cost-effective product, which is evident in the decreasing cost of the transponder even in the light of increasing inflation.

The cost development of the ATCRBS transponder presented in this study attempts to reflect this change in avionics production by comparison of two air-carrier-quality products -- one fully developed and amortized over recent years, and the other recently developed and just entering full production. Both transponders are high-quality units meeting ARINC specifications and are popular within the air carrier community. The two manufacturers whose products are being evaluated are well recognized by the air carrier community and are large suppliers of a variety of avionics used by the carriers.

The general-aviation transponder evaluated in this study is a unit typical of those manufactured by many general-aviation manufacturers. Only the cost of production was developed since the unit is a well established transponder whose development costs have already been amortized. The cost of interest, for comparison purposes, is the manufacturer's cost in today's dollars.

This chapter develops the cost of both classes of transponders by application of the pricing model and presents published prices of the equipment for comparison with the model evaluation. This evaluation was undertaken to develop parametric data on existing systems and permit comparison with data used in the cost development of new systems.

## 4.1 TRANSPONDER COST DEVELOPMENT, HIGH-PERFORMANCE AIRCRAFT

The ATCRBS transponder designed to ARINC specifications is a solid-state electronic device housed in a 3/8-ATR short case. It consists of a transmitter, receiver, decoding and encoding circuitry, and other signal processing and monitoring modules. The units evaluated in this study are modular

in design to allow easy access for replacement of failed assemblies; they are therefore suitable for evaluation by the pricing model on a subassembly basis.

### 4.1.1 Production Version

The unit as fully developed and subject to production-only costs of manufacture comprises 10 easily identifiable subassemblies. The physical description of each subassembly is presented in Table 4-1, together with other

*Table 4-1.* PARAMETER VALUES FOR ATCRBS TRANSPONDER (IN PRODUCTION), HIGH-PERFORMANCE AIRCRAFT

| Parameter | Parameters Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Transmitter | Receiver | IF Amplifier | Video Processor | Control Matrix | Monitor | L.V. Power Supply | Shift Register No. 1 | Shift Register No. 2 | Chassis and Enclosure |
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 |
| WT | .852 | .835 | .382 | .481 | .511 | .511 | .191 | .371 | .371 | 8.077 |
| VOL | .02 | .0195 | .0096 | .01 | .013 | .008 | .004 | .008 | .008 | .228 |
| WS | .772 | .385 | .166 | 0 | 0 | 0 | 0 | 0 | 0 | 8.077 |
| MCPLXS | 7.65 | 6.421 | 5.996 | - | - | - | - | - | - | 5.538 |
| NEWST | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| MCPLXE | 9.313 | 8.814 | 8.144 | 7.983 | 8.045 | 7.980 | 7.814 | 7.825 | 7.865 | - |
| NEWEL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| CMPNTS | 46 | 90 | 170 | 163 | 348 | 107 | 134 | 40 | 45 | - |
| ECMPLX | - | - | - | - | - | - | - | - | - | - |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 |
| ECNE | .005 | .005 | .005 | .005 | .005 | .005 | .005 | .005 | .005 | - |
| ECNS | .005 | .005 | .005 | - | - | - | - | - | - | .005 |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PROJCT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DATA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TLGTST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PLTFM | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |
| SYSTEM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PPROJ | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| PDATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| PTLGTS | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 |

parametric data necessary for the execution of the PRICE model. A typical production quantity of 1000 units per year has been chosen for this study to maintain comparative consistency between the systems evaluated. Table 4-1 shows values of zero for parameters such as new design, engineering complexity, project management, etc., because these control the development costs associated with manufacturing. All other parameters are associated with production and properly define the product to be evaluated. An additional module, the transmitter cavity oscillator, is not shown because this assembly is normally purchased by the transponder manufacturer. The cost of the purchased item, together with handling and overhead costs, is included in the final PRICE evaluations as a special input.

Table 4-2 summarizes the PRICE outputs by subassembly costs and cumulative costs. The last equipment entry, Test and Integration, is a mandatory input when a system cost is developed by subassemblies. Test and Integration accounts for the final assembly of a unit, machining of interface components, power connections, alignment and tuning of electrical subsystems, and the final functional test of the system. The factory Sell Price is the cost of manufacturing with appropriate G&A and profit included; it is the expected selling price to air carriers and distributors. The selling (list) price is the normal cost to private aircraft owners requiring limited quantities of the product.

*Table 4-2.* ATCRBS TRANSPONDER (IN-PRODUCTION) COSTS, HIGH-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Transmitter | N/A | 639.47 | 639 |
| Receiver | N/A | 759.21 | 759 |
| IF Amplifier | N/A | 226.15 | 226 |
| Video Processor | N/A | 349.60 | 350 |
| Control Matrix | N.A | 388.46 | 388 |
| Monitor | N/A | 368.83 | 369 |
| L.V. Power Supply | N/A | 141.96 | 142 |
| Shift Register No. 1 | N/A | 243.56 | 244 |
| Shift Register No. 2 | N/A | 252.31 | 252 |
| Chassis and Enclosure | N/A | 404.05 | 404 |
| Transmitter Cavity | N/A | 40.00 | 40 |
| Test and Integration | N/A | 139.97 | 140 |
| Factory Sell Price | | | 3953 |
| Distributor Markup | | | 1186 |
| List Price | | | 5139 |

### 4.1.2 New-Development Version

The unit described by Table 4-3 is a new-development version initiated in early 1975 by one of the leading avionics manufacturers. The unit is all solid state, including the power amplifier, and consists of 15 identifiable subassemblies. The weight and volume of each subassembly were measured at the manufacturer's plant and therefore are known exactly. The percent of new design of structures and electronics is subjective, based on the expected availability of past designs and adaptability to the transponder effort. A

100 percent design effort was considered for the exciter and power amplifier subassemblies since these are new, state-of-the-art modules. The engineering complexities reflect the subjective interpretations of the development status of subassemblies and are consistent with recommendations published by RCA.

*Table 4-3.* Parameter Values for ATCRBS Transponder (New Development) High-Performance Aircraft

| Parameter | Parameter Values: Video Processor | Functional Test | Decoder/Encoder | Diplexer | Preselector and Mixer | Local Oscillator | IF Amplifier-Detector | D/E Oscillator | Modulator | L.V. Power Supply |
|---|---|---|---|---|---|---|---|---|---|---|
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 |
| WT | .156 | .25 | .25 | .188 | .438 | .141 | .219 | .141 | .094 | .422 |
| VOL | .0028 | .0043 | .0096 | .0021 | .0038 | .0025 | .0043 | .0028 | .0022 | .0052 |
| WS | .044 | .067 | 0 | .188 | .408 | .039 | .067 | .044 | 0 | 0 |
| MCPLXS | 5.867 | 5.247 | - | 8.513 | 6.348 | 5.897 | 5.683 | 6.011 | - | - |
| NEWST | .1 | .1 | - | .5 | .5 | .1 | .1 | .1 | - | - |
| MCPLXE | 8.1 | 7.0 | 7.623 | - | 7.702 | 8.174 | 7.701 | 8.325 | 7.528 | 7.445 |
| NEWEL | .3 | .3 | .7 | - | 1. | .5 | .5 | .3 | .7 | .4 |
| CMPNTS | 63 | 64 | 104 | - | 10 | 35 | 79 | 39 | 62 | 55 |
| ECMPLX | .9 | .9 | .9 | .9 | .4 | .9 | .4 | .4 | .7 | .4 |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 |
| ECNE | .005 | .005 | .005 | - | .001 | .005 | .005 | .005 | .005 | .005 |
| ECNS | .005 | .005 | - | .005 | .005 | .005 | .005 | .005 | - | - |
| YEAR | 1975 | 1975 | 1975 | 1975 | 1975 | 1975 | 1975 | 1975 | 1975 | 1975 |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PROJCT | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| DATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| TLGTST | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 |
| PLTFM | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 |
| PPROJ | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| PDATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| PTLGTS | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 |

(Continued)

| Table 4-3. (Continued) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Parameter Values | | | | | | | | | |
| | Transmitter Oscillator | Exciter | Power Amplifier | Transmitter Power Supply | Enclosure and Chassis | | | | | |
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | | | | | |
| WT | .688 | .188 | .188 | .25 | 5.289 | | | | | |
| VOL | .006 | .0048 | .0048 | .0039 | .147 | | | | | |
| WS | .121 | .074 | .074 | 0 | 5.289 | | | | | |
| MCPLXS | 5.507 | 7.110 | 7.104 | - | 6.213 | | | | | |
| NEWST | .7 | 1. | 1 | - | .3 | | | | | |
| MCPLXE | 7.513 | 10.056 | 10.05 | 7.141 | - | | | | | |
| NEWEL | .7 | 1 | 1 | .5 | - | | | | | |
| CMPNTS | 28 | 48 | 26 | 54 | - | | | | | |
| ECMPLX | .9 | 1 | 1 | .9 | .4 | | | | | |
| PRMTH | 36 | 36 | 36 | 36 | 36 | | | | | |
| LCURVE | .865 | .865 | .865 | .865 | .865 | | | | | |
| ECNE | .005 | .01 | .05 | .005 | - | | | | | |
| ECNS | .005 | .01 | .05 | - | .005 | | | | | |
| YEAR | 1975 | 1975 | 1975 | 1975 | 1975 | | | | | |
| ESC | 0 | 0 | 0 | 0 | 0 | | | | | |
| PROJCT | .5 | .5 | .5 | .5 | .5 | | | | | |
| DATA | .5 | .5 | .5 | .5 | .5 | | | | | |
| TLGTST | .3 | .3 | .3 | .3 | .3 | | | | | |
| PLTFM | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | | | | | |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | | | | | |
| PPROJ | .5 | .5 | .5 | .5 | .5 | | | | | |
| PDATA | .5 | .5 | .5 | .5 | .5 | | | | | |
| PTLGTS | .3 | .3 | .3 | .3 | .3 | | | | | |

Table 4-4 presents the development and production costs of each subassembly with the development costs amortized over the entire 3000 unit production quantity. The outputs developed by the pricing model closely correlate with the subassembly costs provided by the manufacturer. The factory selling price and the list price are the expected costs to air carriers and individual owners, respectively.

Table 4-4. ATCRBS TRANSPONDER (NEW DEVELOPMENT) COSTS, HIGH-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Video Processor | 4.78 | 120.68 | 125 |
| Functional Test | 5.19 | 73.63 | 79 |
| Decoder/Encoder | 2.99 | 147.93 | 151 |
| Diplexer | 4.05 | 249.72 | 254 |
| Preselector and Mixer | 5.21 | 99.05 | 104 |
| Local Oscillator | 0.97 | 118.67 | 120 |
| IF Amplifier-Detector | 5.17 | 113.75 | 119 |
| D/E Oscillator | 3.32 | 130.12 | 133 |
| Modulator | 6.20 | 58.82 | 65 |
| L.V. Power Supply | 7.77 | 201.23 | 209 |
| Transmitter Oscillator | 29.69 | 291.51 | 321 |
| Exciter | 42.28 | 688.06 | 730 |
| Power Amplifier | 42.19 | 694.75 | 737 |
| Transmitter Power Supply | 9.53 | 98.21 | 108 |
| Enclosure/Chassis | 8.94 | 546.73 | 556 |
| Test and Integration | 4.63 | 160.73 | 165 |
| Factory Sell Price | | | 3975 |
| Distributor Markup | | | 1193 |
| List Price | | | 5169 |

## 4.2 TRANSPONDER COST DEVELOPMENT, LOW-PERFORMANCE AIRCRAFT

The transponder evaluated in this study is a standard general-aviation unit meeting Technical Service Order (TSO) C74b for Class I service designed to be installed in the flight console of single-engine and light twin-engine aircraft. The unit consists of a main printed circuit card containing all the decoding, encoding, and processing logic and circuitry necessary for the operation of the transponder; a subassembly containing the logarithmic receiver; a mechanical preselector/filter assembly; a cavity oscillator; and the enclosure with front panel controls. All assemblies except the cavity oscillator are manufactured by the general-aviation manufacturer. The cavity oscillator is usually purchased from tube manufacturers. Table 4-5 presents the physical descriptions of the transponder in the input format of the pricing model. Production quantities of 1000 units per year have been chosen for this study as typical of the production rate in the general-aviation community for products that have been on the market for a number of years. Frequent modifications and improvements of the basic development program have dictated that this evaluation assume continuing engineering costs, although the development costs are considered amortized. The physical characteristics of the subassemblies, i.e., the weight and volume, were measured at the manufacturer's plant and are considered accurate. Variations in the platform, system management, tooling, test equipment, etc., between the general-aviation and air carrier manufacturers shown in this table and Tables 4-1 and 4-3 are

Table 4-5. PARAMETER VALUES FOR ATCRBS TRANSPONDER, LOW-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values: Main PC Card | Receiver | Preselector/Filter | Front Panel and Chassis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| QTY | 3000 | 3000 | 3000 | 3000 | | | | | | |
| WT | .631 | .38 | .5 | 1.3 | | | | | | |
| VOL | .0228 | .0068 | .01 | .07 | | | | | | |
| WS | 0 | .1 | .5 | 1.3 | | | | | | |
| MCPLXS | - | 3.922 | 4.279 | 4.270 | | | | | | |
| NEWST | - | .2 | .5 | .5 | | | | | | |
| MCPLXE | 6.299 | 6.012 | - | - | | | | | | |
| NEWEL | 1 | .5 | - | - | | | | | | |
| CMPNTS | 90 | 123 | - | - | | | | | | |
| ECMPLX | .9 | .4 | .7 | .4 | | | | | | |
| PRMTH | 36 | 36 | 36 | 36 | | | | | | |
| LCURVE | .865 | .865 | .865 | .865 | | | | | | |
| ECNE | .05 | .01 | - | - | | | | | | |
| ECNS | - | .01 | .01 | .005 | | | | | | |
| YEAR | 1976 | 1976 | 1976 | 1976 | | | | | | |
| ESC | 0 | 0 | 0 | 0 | | | | | | |
| PROJCT | .5 | .5 | .5 | .5 | | | | | | |
| DATA | .5 | .5 | .5 | .5 | | | | | | |
| TLGTST | .2 | .2 | .2 | .2 | | | | | | |
| PLTFM | 1.6 | 1.6 | 1.6 | 1.6 | | | | | | |
| SYSTEM | .3 | .3 | .3 | .3 | | | | | | |
| PPROJ | .3 | .3 | .3 | .3 | | | | | | |
| PDATA | .3 | .3 | .3 | .3 | | | | | | |
| PTLGTS | .2 | .2 | .2 | .2 | | | | | | |

caused by the differences in the manufacturing environment and quality of the final product; they were determined through sensitivity analyses performed with the pricing model on the two classes of manufacturers.

Table 4-6 presents the results of the PRICE model evaluation. Development costs are assumed to be amortized for this transponder since it has been in the manufacturer's inventory for a number of years. The production costs developed by the model result in a factory sell price very close to the known cost to the manufacturer. The normal practice of 100 percent markup for distribution results in the list price of $612.

*Table 4-6.* ATCRBS TRANSPONDER COSTS, LOW-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Main PC Card | N/A | 129.50 | 130 |
| Receiver | N/A | 55.04 | 55 |
| Transmitter Cavity | N/A | 40.00 | 40 |
| Preselector/Filter | N/A | 18.50 | 19 |
| Front Panel/Chassis | N/A | 37.35 | 37 |
| Test and Integration | N/A | 24.95 | 25 |
| Factory Sell Price | | | 306 |
| Distributor Markup | | | 306 |
| List Price | | | 612 |

## 4.3 SUMMARY

The cost of air carrier and general-aviation transponders developed by the pricing model are summarized in Table 4-7 and compared with published prices for the appropriate user communities. In addition, the costs of controls and antennas from manufacturers' price lists have been included to provide the total equipment cost for a single system implementation in air carrier, high-performance general-aviation, and low-performance general-aviation aircraft. The close correlation between the model-developed costs and manufacturers' prices highlights the model's ability to estimate costs when careful attention is given to the development of parametric data required for execution of the model.

*Table 4-7.* ATCRBS AVIONICS COSTS (SINGLE SYSTEM PER AIRCRAFT)

| Equipment | Cost (in dollars) by User Aircraft Category | | | | | |
|---|---|---|---|---|---|---|
| | Air Carrier | | High-Performance Aircraft | | Low-Performance Aircraft | |
| | Manufacturer Price Lists | PRICE-Developed | Manufacturer Price Lists | PRICE-Developed | Manufacturer Price Lists | PRICE-Developed |
| Transponder | | | | | | |
| . In Production | 3988 | 3953 | 5184 | 5139 | 595 | 612 |
| . New Development | 3991 | 3975 | 5188 | 5169 | - | - |
| Control | 516 | 516* | 516 | 516* | N/A | N/A |
| Antenna | 63 | 63* | 75 | 75* | 13 | 13* |
| Total Cost** | 4567 | 4532 | 5775 | 5730 | 608 | 625 |

*From manufacturers' price lists **In production

## *CHAPTER FIVE*

## DISCRETE ADDRESS BEACON SYSTEM (DABS)

In the future, secondary surveillance will be accomplished with the use of the DABS concept, discretely addressing each aircraft and thereby eliminating the synchronous-garble problems experienced in dense traffic environments. The DABS concept will also provide a data link capability between aircraft in flight and ground control, which will enhance system operation by providing ATC message capability and separation assurance through the use of Intermittent Positive Control (IPC), and could lead to a reduction in the controller workload through automation of many of the functions now performed by air traffic controllers.

This chapter addresses the cost development of the avionics required to implement the surveillance function of the DABS concept. The designs considered are based on the systems evaluated in report FAA-EM-76-2 (Reference 3). With the large number of units expected to be manufactured over the DABS implementation period, large-scale integration (LSI) appears to be the most cost-effective approach to solving the complex logic requirements of DABS. This is the only exception to the technology ground rule used for all other systems.

Two versions of the airborne equipment are subjected to the pricing model for evaluation and cost estimating: the transponder designed to ARINC specifications and intended for the air carriers and other high-performance aircraft, and the transponder designed to general-aviation standards and intended for the single-engine and light twin-engine aircraft.

This chapter presents the physical and economic descriptors of the DABS avionics and the results of the PRICE model evaluation.

### 5.1 DABS TRANSPONDER COST DEVELOPMENT, HIGH-PERFORMANCE AIRCRAFT

The DABS transponder designed to ARINC specifications is a solid-state electronic device housed in a 3/8-ATR long case. It consists of a transmitter, dual receivers and IF amplifiers, decoding and encoding circuitry, and other signal processing and monitoring modules. The units evaluated in this study are expected to be modular in design to allow easy access for replacement of failed assemblies; they are therefore suitable for evaluation by the pricing model on a subassembly basis. Many of the modules will probably be common to the ATCRBS transponders since they perform identical functions. The physical descriptors presented in Table 5-1 were obtained from existing ATCRBS transponder modules and from design configurations and parts identification

*Table 5-1.* PARAMETER VALUES FOR DABS TRANSPONDER, HIGH-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Transmitter | Receiver (2 each) | IF Amplifier (2 each) | Video Processor | Control Matrix | Monitor | Low Voltage Power Supply | Logic | Chassis | | |
| QTY | 3000 | 6000 | 6000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | | |
| WT | .852 | .832 | .382 | .481 | .511 | .411 | .201 | .376 | 8.077 | | |
| VOL | .02 | .0195 | .0096 | .01 | .013 | .008 | .004 | .008 | .228 | | |
| WS | .772 | .385 | .166 | 0 | 0 | 0 | 0 | 0 | 8.077 | | |
| MCPLXS | 7.650 | 6.421 | 5.996 | - | - | - | - | - | 5.538 | | |
| NEWST | .1 | .2 | .2 | - | - | - | - | - | .3 | | |
| MCPLXE | 9.313 | 8.814 | 8.144 | 7.983 | 8.045 | 7.980 | 8.214 | 8.556 | - | | |
| NEWEL | .2 | .3 | .2 | .2 | .2 | .2 | .3 | 1. | - | | |
| CMONTS | 46 | 93 | 170 | 163 | 348 | 107 | 139 | 21 | - | | |
| ECMPLX | .4 | .4 | .4 | .4 | .4 | .4 | .4 | 1.5 | .4 | | |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | | |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | | |
| ECNE | .005 | .005 | .005 | .005 | .005 | .005 | .01 | .01 | - | | |
| ECNS | .005 | .005 | .005 | - | - | - | - | - | .005 | | |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | | |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROJCT | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | | |
| DATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | | |
| TLGTST | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | | |
| PLTFM | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | | |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | | |
| PPROJ | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | | |
| PDATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | | |
| PTLGTS | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | | |

developed in Reference 3. Development costs have been included in the model evaluation, but those modules expected to be common with existing design have been described parametrically to reflect second-generation, *minimum* new design requirements.

The results of exercising the pricing model are presented in Table 5-2. Direct comparison of similar-function modules with data presented in Table 4-2 shows minor variation in the predicted cost of production of the modules. Although similar, the modules are not identical, as is evident from the amount of new design shown in Table 5-1. The new design can be either expansion of capability of the module (e.g., a more rugged transmitter capable of longer duty factors), which is reflected in the higher cost, or reduction of functional requirements (e.g., monitor card's MODE D detection function) not required for DABS operation, which is reflected in a lower module cost. The development costs, presented on a per unit basis, reflect the proportional costs of engineering and prototype production when amortized over the entire production quantity of 3000 DABS transponders. The high cost of logic development reflects the expected investment in LSI development. The factory selling price of $5212 is the expected cost of the transponder to air carriers and distributors who buy large quantities from the manufacturer. The 30 percent markup results in a cost of $6776, which is the list price expected to be paid by the individual aircraft owners or small fleets that require the ARINC-specified avionics.

*Table 5-2.* DABS TRANSPONDER (LSI VERSION) COSTS, HIGH-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Transmitter | 4.51 | 675.40 | 680 |
| Receiver (2 each) | 4.30 | 723.28 | 1455 |
| IF Amplifier (2 each) | 1.64 | 215.71 | 435 |
| Video Processor | 4.71 | 379.71 | 384 |
| Control Matrix | 4.81 | 421.84 | 427 |
| Monitor | 4.31 | 330.61 | 335 |
| L.V. Power Supply | 4.01 | 218.52 | 223 |
| Digital Logic | 60.35 | 521.37 | 582 |
| Chassis | 5.33 | 433.84 | 439 |
| Transmitter Cavity | - | 40.00 | 40 |
| Test and Integration | 3.25 | 208.67 | 212 |
| Factory Sell Price | | | 5212 |
| Distributor Markup | | | 1564 |
| List Price | | | 6776 |

## 5.2 DABS TRANSPONDER COST DEVELOPMENT, LOW-PERFORMANCE AIRCRAFT

Table 5-3 defines a general-aviation version of the DABS transponder evaluated in Section 5.1. Functionally, the unit performs the same surveillance operations as the high-performance version but does not require diversity operation and operates at a lower output power. In addition, the version chosen for evaluation (on the basis of details developed in Reference 3) includes the logic and display of the IPC/PWI capability of separation assurance. Designed to be mounted in the flight console of single-engine and light twin-engine aircraft, the DABS transponder will replace the present ATCRBS transponder, from which many design features and functional characteristics were

| Table 5-3. Parameter Values for DABS Transponder, Low-Performance Aircraft | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Parameter Values | | | | | | | | | |
| Parameter | Transmitter-Modulator | Receiver | Power Supply | Analog Logic | Digital Logic | Front Panel and Chassis | | | | |
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | | | | |
| WT | .188 | .4 | .188 | .188 | .3125 | 1.5 | | | | |
| VOL | .0029 | .007 | .0029 | .0029 | .007 | .099 | | | | |
| WS | 0 | .1 | 0 | 0 | 0 | 1.3 | | | | |
| MCPLXS | - | 4.746 | - | - | - | 5.142 | | | | |
| NEWST | - | .2 | - | - | - | .3 | | | | |
| MCPLXE | 5.471 | 6.412 | 5.714 | 5.851 | 7.982 | 6.054 | | | | |
| NEWEL | .2 | .3 | .1 | .3 | 1. | .3 | | | | |
| CMPNTS | 36 | 173 | 31 | 49 | 35 | 74 | | | | |
| ECMPLX | .4 | .4 | .4 | .4 | 1.0 | .5 | | | | |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 | | | | |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .865 | | | | |
| ECNE | .005 | .01 | .005 | .01 | .01 | .01 | | | | |
| ECNS | - | .001 | - | - | - | .01 | | | | |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | | | | |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| PROJCT | .5 | .5 | .5 | .5 | .5 | .5 | | | | |
| DATA | .5 | .5 | .5 | .5 | .5 | .5 | | | | |
| TLGTST | .2 | .2 | .2 | .2 | .2 | .2 | | | | |
| PLTFM | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | | | | |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | .3 | | | | |
| PPROJ | .3 | .3 | .3 | .3 | .3 | .3 | | | | |
| PDATA | .3 | .3 | .3 | .3 | .3 | .3 | | | | |
| PTLGTS | .2 | .2 | .2 | .2 | .2 | .2 | | | | |

derived because of the similarity of performance requirements. The DABS transponder consists of the six modules identified in Table 5-3 and a cavity oscillator that provides the transmitter function of the transponder. Only six modules were subjected to evaluation by the pricing model because the cavity is normally purchased by the manufacturer and must be treated as a special input to the model.

Table 5-4 presents the results of the PRICE evaluation. The factory selling price of $676 is the predicted cost to the manufacturer when overhead and profit are included. The normal practice of a 100 percent markup for owners of low-performance aircraft has resulted in the expected list price of $1352, which would be paid by the private aircraft owners requiring DABS avionics.

*Table 5-4.* DABS TRANSPONDER (LSI VERSION) COSTS, LOW-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Transmitter/Modulator | .83 | 23.38 | 24 |
| Transmitter Cavity | - | 40.00 | 40 |
| Receiver | 1.91 | 83.48 | 85 |
| Power Supply | .47 | 28.55 | 29 |
| Analog Logic | 1.35 | 32.16 | 34 |
| Digital Logic | 17.08 | 285.25 | 302 |
| Front Panel Chassis | 1.88 | 120.80 | 123 |
| Test and Integration | .36 | 39.11 | 39 |
| Factory Sell Price | | | 676 |
| Distributor Markup | | | 676 |
| List Price | | | 1352 |

## 5.3 SUMMARY

The cost of avionics required for implementation of DABS must include the associated controls and antennas and will probably require a separation-assurance command indicator such as the IPC/PWI display (cost developed in Chapter Seven). Table 5-5 presents the expected cost of avionics to implement a single (nonredundant) DABS system in an aircraft for each of the three classes of users: the air carriers, high-performance general aviation, and low-performance general aviation. The cost of controls and antennas has been taken from manufacturers' price lists, while costs of transponders and displays were developed by the pricing model.

Table 5-5. DABS/IPC AVIONICS COST SUMMARY

| Equipment | Air Carrier | High-Performance General Aviation | Low-Performance General Aviation |
|---|---|---|---|
| Transponder | 5212 | 6776 | 1352 |
| IPC/PWI Display | 2198 | 2857 | ** |
| Control | 516* | 516* | ** |
| Antenna (2 each) | 126* | 150* | 13* |
| Total Cost | | | 1365 |

*From manufacturers' price lists.
**Included in electronics package.

# CHAPTER SIX

## SELECTIVE ADDRESS BEACON (SAB) SYSTEM

The system designed primarily to reduce the effects of synchronous garble is a compromise between the existing ATCRBS and the proposed DABS concepts. This system, the Selective Address Beacon (SAB), uses the assigned 4096 code of all IFR aircraft and VFR aircraft in contact with the ATC facility to selectively interrogate each aircraft. The avionics must operate in the normal ATCRBS mode as well as the SAB mode when interrogated by a SAB ground station. The operation of the airborne transponder requires detection of the side lobe suppression (SLS) pulse pair and processing of the additional 4096 coded data included in a SAB interrogation for comparison with the transponder's own assigned code. Correlation of the codes will result in the transponder transmission of a standard identity reply, whereas recognition of a variation in the codes will cause the transponder to suppress replies for the specified 35 μsec SLS period.

The MITRE study (Reference 1), which defines the operational characteristics of the SAB, recommends that SAB avionics be considered only for the class of users requiring high-quality (assumed ARINC specification) equipment. This report is uniformly developing costs of avionics for three classes of users -- the air carriers, high-performance general aviation, and low-performance general aviation -- and provides for the probability that exists for low-performance aircraft to be in the mixed airspace, where the benefits of SAB are required to improve flight safety. Therefore, the development of SAB avionics includes equipment suitable for all classes of users.

### 6.1 SAB TRANSPONDER, HIGH-PERFORMANCE AIRCRAFT

The operational performance of the SAB transponder includes all of the features identified for an ATCRBS transponder (Chapter Four), as well as additional decoding logic to handle the extended interrogation message and comparison logic for matching the interrogator 4096 code with the aircraft's code entered through the control panel. The interrogator signal format, proposed by Reference 1, uses the standard 15-bit ATCRBS reply format with two SLS pulses and does not include parity checks or error correction. Therefore, the logic required is slightly less complex than the logic developed in Reference 5. However, the general description of the SAB concept developed in Reference 5 for the 4096 code transponder applies to this evaluation. The transponder is designed to ARINC specifications for packaging in a 3/8-ATR enclosure meeting the environmental requirements for air carrier avionics.

Table 6-1 presents the physical and economic descriptors of the SAB transponder. All subassemblies except SAB logic are identical to those describing the "in production" version of ATCRBS transponder presented in Chapter Four. The adaptation of the ATCRBS transponder is justified on the grounds that the SAB system must perform all ATCRBS functions in addition to the selective address decoding and control of SAB. The SAB logic processing can be integrated on a single printed circuit card since it requires only one shift register, six comparator chips, and miscellaneous ICs and discrete components for controling and enabling the identity reply encoder. By careful design of the ATCRBS chassis, the SAB logic card can be included in the 3/8-ATR enclosure without extending the length of the unit.

*Table 6-1.* PARAMETER VALUES FOR SAB TRANSPONDER, HIGH-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Transmitter | Receiver | IF Amplifier | Video Processor | Control Matrix | Monitor | L.V. Power Supply | Shift Register No. 1 | Shift Register No. 2 | SAB Logic | Chassis and Enclosure |
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 |
| WT | .852 | .835 | .382 | .481 | .511 | .511 | .191 | .371 | .371 | .25 | 8.077 |
| VOL | .02 | .0195 | .0096 | .01 | .013 | .008 | .004 | .008 | .008 | .0096 | .228 |
| WS | .772 | .385 | .166 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.077 |
| MCPLXS | 7.65 | 6.421 | 5.996 | - | - | - | - | - | - | - | 5.538 |
| NEWST | 0 | 0 | 0 | - | - | - | - | - | - | - | .1 |
| MCPLXE | 9.313 | 8.814 | 8.144 | 7.983 | 8.045 | 7.980 | 7.814 | 7.825 | 7.865 | 7.865 | - |
| NEWEL | 0 | 0 | 0 | 0 | .1 | 0 | 0 | .1 | .1 | 1. | - |
| CMPNTS | 46 | 90 | 170 | 163 | 360 | 107 | 139 | 45 | 50 | 48 | - |
| ECMPLX | - | - | - | - | .4 | - | - | .4 | .4 | .9 | .4 |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 |
| ECNE | .005 | .005 | .005 | .005 | .005 | .005 | .01 | .005 | .005 | .01 | - |
| ECNS | .005 | .005 | .005 | - | - | - | - | - | - | - | .005 |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PROJCT | 0 | 0 | 0 | 0 | .5 | 0 | 0 | .5 | .5 | .5 | .5 |
| DATA | 0 | 0 | 0 | 0 | .5 | 0 | 0 | .5 | .5 | .5 | .5 |
| TLGTST | 0 | 0 | 0 | 0 | .3 | 0 | 0 | .3 | .3 | .3 | .3 |
| PLTFM | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |
| SYSTEM | 0 | 0 | 0 | 0 | .3 | 0 | 0 | .3 | .3 | .3 | .3 |
| PPROJ | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| PDATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| PTLGTS | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 |

Table 6-2 presents the results of the pricing model evaluation of the SAB transponder. The development costs for modules common to the ATCRBS transponder have been eliminated under the assumption that they were amortized in ATCRBS development. Development costs are presented for the SAB logic, enclosure and chassis, and processing modules because these will require some new design to operate in the combined SAB/ATCRBS system. The $4176 selling price to air carriers includes the increase resulting from the addition of SAB logic to a conventional ATCRBS transponder when the addition is integrated by the manufacturer. The total development cost of $36,000 has been assumed amortized over the production quantity of 3000 units.

*Table 6-2.* SAB TRANSPONDER COSTS, HIGH-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Transmitter | N/A | 639 | 639 |
| Receiver | N/A | 759 | 759 |
| IF Amplifier | N/A | 226 | 226 |
| Video Processor | N/A | 350 | 350 |
| Control Matrix | 1.00 | 398 | 399 |
| Monitor | N/A | 369 | 369 |
| L.V. Power Supply | N/A | 142 | 142 |
| Shift Register No. 1 | 1.00 | 249 | 250 |
| Shift Register No. 2 | 1.00 | 258 | 259 |
| SAB Logic | 8.00 | 193 | 201 |
| Chassis and Enclosure | 1.00 | 403 | 404 |
| Transmitter Cavity | N/A | 40 | 40 |
| Test and Integration | 1.00 | 137 | 138 |
| Factory Sell Price | | | 4176 |
| Distributor Markup | | | 1253 |
| List Price | | | 5429 |

study, it is assumed that the manufacturer of the ATCRBS transponder would produce the SAB electronics as a new product and thus development and production costs are included in the cost of manufacturing. The SAB transponder is expected to reuse the preselector, filter, and receiver common to ATCRBS, as well as the same transmitter cavity oscillator; but all timing, decoding, encoding, and power supply circuitry will be new, requiring engineering development. Table 6-3 presents the physical and economic parameters describing the SAB transponder and the general-aviation manufacturer. The receiver and preselector have been treated as production-only items by eliminating the new design requirements and minimizing the engineering complexity associated with unit development.

## 6.2 SAB TRANSPONDER, LOW-PERFORMANCE AIRCRAFT

The operational capability of the SAB transponder for general-aviation low-performance aircraft is the same as that specified for the high-performance equipment. However, the general-aviation equipment is generally not suitable for module addition and must be redesigned to include additional functions on the one or two printed circuit boards of the equipment. In this

Table 6-3. PARAMETER VALUES FOR SAB TRANSPONDER, HIGH-PERFORMANCE AIRCRAFT

| Parameter | Receiver | Preselector/Filter | PC Card No. 1 | PC Card No. 2 | Front Panel and Enclosure |
|---|---|---|---|---|---|
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 |
| WT | .38 | .5 | .5 | .38 | 1.5 |
| VOL | .0068 | .01 | .0184 | .014 | .091 |
| WS | .1 | .5 | 0 | 0 | .091 |
| MCPLXS | 3.922 | 4.279 | - | - | 4.270 |
| NEWST | 0 | 0 | - | - | .3 |
| MCPLXE | 6.012 | - | 6.299 | 6.299 | - |
| NEWEL | 0 | - | .3 | .7 | - |
| CMPNTS | 123 | - | 60 | 55 | - |
| ECMPLX | .4 | .4 | .9 | .9 | .4 |
| PRMTH | 36 | 36 | 36 | 36 | 36 |
| LCURVE | .865 | .865 | .865 | .865 | .865 |
| ECNE | .01 | - | .01 | .01 | - |
| ECNS | .01 | .01 | - | - | .01 |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 |
| ESC | 0 | 0 | 0 | 0 | 0 |
| PROJCT | 0 | 0 | .5 | .5 | .5 |
| DATA | 0 | 0 | .5 | .5 | .5 |
| TLGTST | 0 | 0 | .2 | .2 | .2 |
| PLTFM | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| SYSTEM | .3 | .3 | .3 | .3 | .3 |
| PPROJ | .3 | .3 | .3 | .3 | .3 |
| PDATA | .3 | .3 | .3 | .3 | .3 |
| PTLGTS | .2 | .2 | .2 | .2 | .2 |

The results of exercising the pricing model are presented in Table 6-4. Development costs are identified for the subassemblies requiring new design that incorporates the SAB functions. The development costs have been amortized over the entire production quantity considered in the study. The $784 cost of avionics to the private aircraft owner includes distributor markup common to this class of user.

*Table 6-4.* SAB TRANSPONDER COSTS, LOW-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Receiver | N/A | 55.04 | 55 |
| Preselector/Filter | N/A | 18.50 | 19 |
| Cavity Oscillator | N/A | 40.00 | 40 |
| PC Card No. 1 | 5.89 | 105.06 | 111 |
| PC Card No. 2 | 7.42 | 83.53 | 91 |
| Front Panel and Enclosure | 1.06 | 41.78 | 43 |
| Test and Integration | 0.43 | 32.24 | 33 |
| Factory Sell Price | | | 392 |
| Distributor Markup | | | 392 |
| List Price | | | 784 |

## 6.3 SUMMARY

The implementation of SAB in air carrier and other high-performance aircraft requires an antenna and control to complement the transponder developed in this study. Table 6-5 identifies the equipment necessary for a single system implementation in aircraft for each of the three user communities considered in the study. Costs of complementary equipment were obtained from published price lists of avionics manufacturers. Equipment intended for low-performance aircraft such as single-engine and light twin-engine airframes includes only the transponder and antenna since the controls are built into the avionics package.

*Table 6-5.* SAB AVIONICS COSTS (SINGLE SYSTEM PER AIRCRAFT)

| Equipment | Costs (in dollars) by Aircraft Category | | |
|---|---|---|---|
| | Air Carrier | High-Performance General Aviation | Low-Performance General Aviation |
| Transponder | 4176 | 5429 | 784 |
| Control* | 516 | 516 | N/A |
| Antenna* | 63 | 75 | 13 |
| Total Cost | 4755 | 6020 | 797 |

*From manufacturers' price lists

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CHAPTER SEVEN

VHF DATA LINK

The ability to communicate information between aircraft in flight and ground facilities is a critical requirement in the operation of present and future air traffic control systems. The information may be in the form of voice or digitized data and include such items as clearances, headings, frequency assignments, or separation-assurance advisories and commands. In the evaluation of alternatives for the upgraded third-generation ATC, MITRE/METREK has identified three VHF concepts that may provide the communications required in present and future operations: (1) the present voice-only VHF communications, (2) the basic VHF data link providing ATC functions and displays to the pilot, and (3) an extended VHF data link providing both the ATC functions and IPC/PWI display information to the pilot. The latter, as proposed by MITRE/METREK, would require automatic ground control of the airborne transceiver tuning to ensure reception of the IPC command on a guard frequency without the need for pilot intervention. Sufficient information is presented in the MITRE/METREK report to allow the start of design engineering of each concept, but a pronounced void is noted in the definition of both the type of data to be transmitted on the ATC data link and the channel-management requirements of the ATC data link.

ARINC Research has attempted to provide reasonable interpretations of the MITRE/METREK VHF concepts based on information presented in other FAA-sponsored studies (e.g., FAA RD-74-189, DABS: A System Description) in developing the probable ATC data and IPC/PWI information to be displayed and the channel management required to operate the system successfully.

This chapter documents the VHF concepts considered for evaluation and provides the results of the cost estimating exercise using the pricing model.

## 7.1 VHF CONCEPT TO BE EVALUATED

ATC communications over the VHF frequency band assigned to air traffic control are currently in the form of voice-only modulation. ATC-associated operations over privately owned air carrier communications networks are being converted to a low-speed (2400 bps) digital data transmission system employing differential-frequency-shift-keying (DFSK) modulation techniques. The success experienced by the airline-owned system provides the necessary background for design and definition of the VHF data link equipments proposed for alternative analysis by MITRE/METREK.

Figures 7-1 through 7-3 are block diagrams of equipments required in support of each of the VHF concepts. The basic VHF communications, Figure 7-1, reflects the existing system on the majority of aircraft in service. Both the high-performance and low-performance aircraft have at least one of these systems, although for the latter case the control function is integral to the transceiver. Figure 7-2 presents the basic VHF data link using a similar (or existing) transceiver but requiring a new data modem capable of two-way data transfer, logic decoding and encoding, selective addressing, and an ATC display. The ATC display, shown in Figure 7-4, is the same as proposed for use with the DABS concept, providing heading, altitude, airspeed, and 16 ASCII characters of free text. Reply and acknowledgement functions, although provided, are not shown. The operation of this concept is adaptable to both high-performance and low-performance aircraft.

Figure 7-3 depicts the extended VHF data link with IPC. This concept provides the same ATC data display as the basic VHF data link but includes separation assurance through display of IPC commands and PWI advisories as shown in Figure 7-5. The concept, as proposed by MITRE, requires ground control of airborne-transceiver channel selection to ensure that the receiver is tuned to the IPC frequency for receipt of commands or advisories. Airborne transceivers equipped with remote controls and using two out of five tuning schemes can have "auto-tune" devices installed in the control lines and be driven by data decoded by the D/L modem. Unfortunately, only the high-performance aircraft avionics provide remotely mounted transceiver controls, limiting this concept to that family of users. This study however, develops the cost of components for both user communities, eliminating only the auto-tune functions from the general-aviation low-performance community.

The modem required to support this concept is the same as shown for the basic VHF data link, having the capability of routing decoded data to the appropriate I/O device. The functional block diagram of the modem is presented in Figure 7-6. The unit is designed to accept DFSK or MSK data at clock rates of 2400 or 4800 bps, depending on the clocks provided, and through the use of 8-bit ASCII coding (7 bits plus parity), decode a message in real time one word at a time. A detailed description of the modem, with supporting diagrams and parts lists, is developed and documented in Reference 4.

## 7.2 AVIONICS COST DEVELOPMENT, HIGH-PERFORMANCE AIRCRAFT

The three VHF options identified for evaluation require a standard VHF transceiver designed to ARINC specifications as the RF-to-baseband signal converter. In addition, the basic and extended data links require a data processing modem with appropriate remotely mounted displays. The extended data link must also provide automatic control of the transceiver and additional pilot displays. This section develops the cost of each item of avionics required to assemble the three options considered and summarizes the expected cost of implementation of each concept in aircraft requiring the high-performance equipment.

### 7.2.1 VHF Transceiver

The transceiver chosen for evaluation is a standard item of avionics in

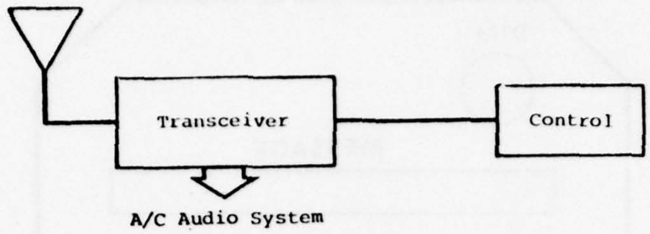


*Figure 7-1.* BASIC VHF COMMUNICATIONS

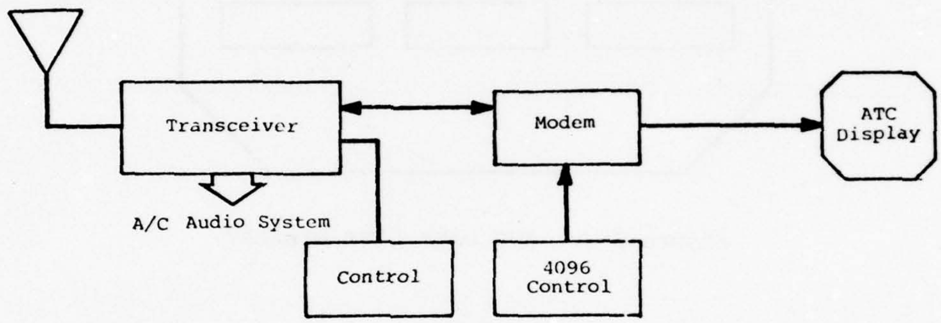


*Figure 7-2.* BASIC VHF DATA LINK

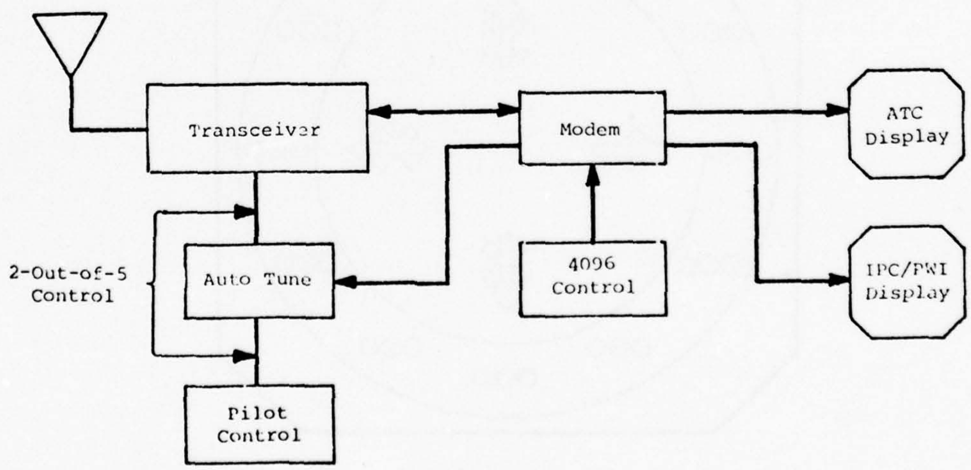


*Figure 7-3.* EXTENDED VHF DATA LINK PLUS IPC

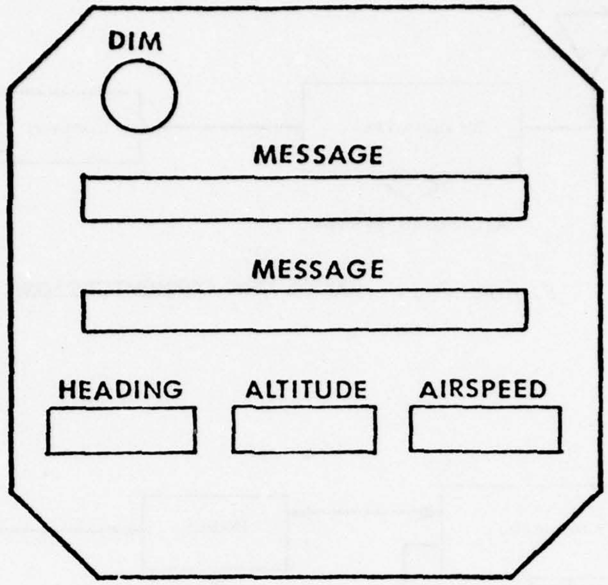


*Figure 7-4.* ATC DATA LINK DISPLAY

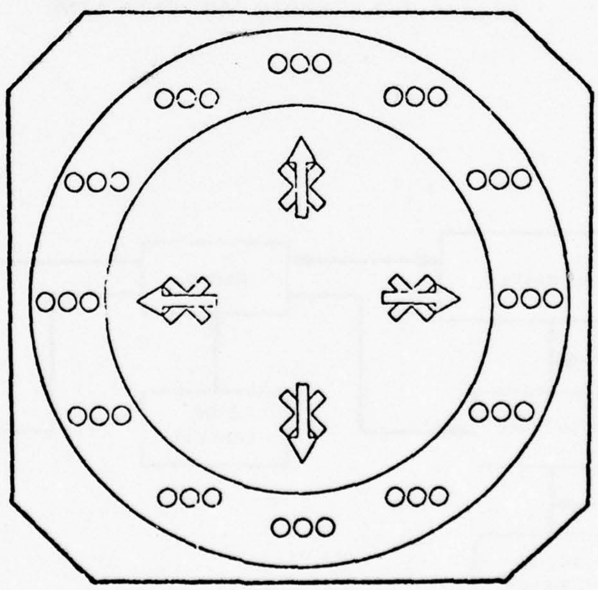

*Figure 7-5.* IPC/PWI COMMAND INDICATOR

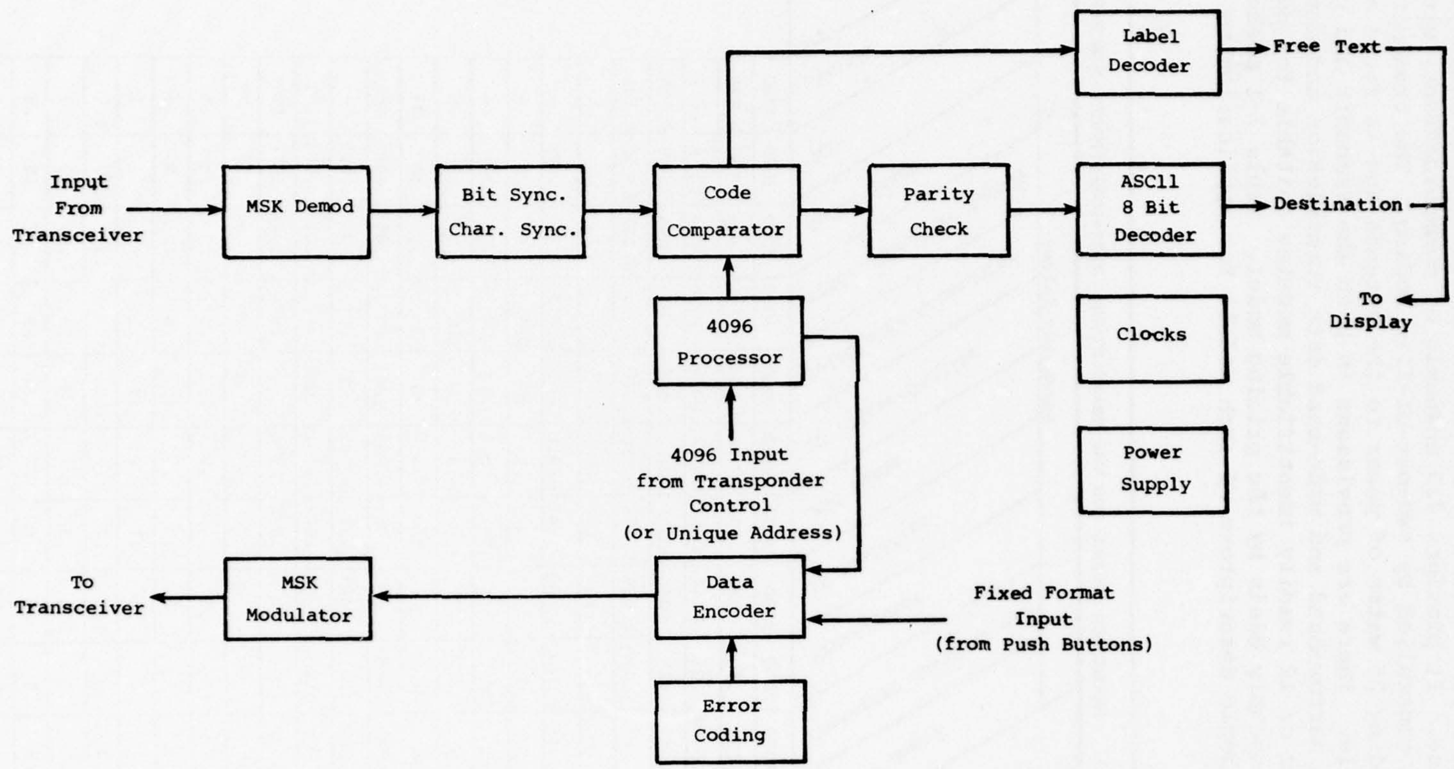


*Figure 7-6.* VHF DATA LINK MODEM BLOCK DIAGRAM

air carrier inventory, designed to ARINC specifications and housed in a 1/2-ATR short case. It provides 720 channels of communications, with frequency selection controlled by two-out-of-five coding. The transmitter is capable of providing 25 watts of power to the antenna and is rated at continuous duty cycle. There are provisions in both the transmit and receive modules for both narrow-band and wide-band data transmission and detection. The unit consists of 12 readily identifiable modules suitable for cost estimating on a subassembly basis by the pricing model. Table 7-1 presents the physical and economic descriptors of each module for application to the PRICE model.

*Table 7-1.* PARAMETER VALUES FOR VHF TRANSCEIVER, HIGH-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Divider Board | Converter Board (2 ea) | Preselector | IF Amplifier | AGC Board | IF Filter-Coupler | Selectable Attenuator | Trans./Mod./Pwr Supply | Audio Board | VCO | Chassis |
| QYT | 3000 | 6000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 |
| WT | .376 | .172 | .55 | .281 | .102 | .036 | .199 | 1.751 | .379 | .156 | 8.826 |
| VOL | .0055 | .0059 | .01 | .0046 | .0019 | .0007 | .0029 | .056 | .0063 | .0014 | .212 |
| WS | 0 | 0 | .145 | .046 | .031 | .012 | .055 | 0 | .095 | .069 | 8,826 |
| MCPLXS | - | - | 5.370 | 4.936 | 5.775 | 5.162 | 5.260 | - | 5.442 | 4.950 | 6.141 |
| NEWST | - | - | 1. | .1 | .1 | .1 | 1. | - | .3 | .5 | .5 |
| MCPLXE | 8.075 | 5.998 | 7.318 | 6.689 | 7.945 | 6.920 | 7.127 | 6.977 | 7.442 | 6.476 | - |
| NEWEL | .5 | .5 | 1.0 | .5 | .3 | .3 | .5 | 1.0 | .5 | .8 | - |
| CMPNTS | 191 | 155 | 55 | 71 | 34 | 8 | 36 | 50 | 170 | 74 | - |
| ECMPLX | 1.0 | .9 | .4 | .4 | .9 | .4 | 1.0 | 1.0 | .9 | .9 | .9 |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 |
| ECNE | .01 | .001 | .01 | .001 | .01 | .001 | .01 | .01 | .01 | .005 | - |
| ECNS | - | - | .01 | .001 | .001 | .001 | .001 | - | .01 | .005 | .01 |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PROJCT | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| DATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| TLGTST | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 |
| PLTFM | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 |
| PPROJ | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| PDATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 |
| PTLGTS | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 |

The tooling and test equipment requirements for development and production are lower than normally expected for this manufacturer because of the existence of VHF transceivers for many years. The manufacturer is expected to have sufficient equipment in inventory, requiring only a nominal increase of tooling for manufacture. The weights and volumes of each module were carefully measured at the manufacturer's plant and are considered accurate for adaptation to the model. A combination of new and second-generation designs has been indicated through the Engineering Complexity descriptor to account for the probability of reusing subassemblies developed for earlier models of VHF transceivers.

Table 7-2 presents the results of the pricing-model exercise. The factory selling price of $2500 developed by the model compares favorably with published manufacturer's price of $2477 for this transceiver. The list price of $3250 shown in the table is the expected cost to individual aircraft owners requiring this class of avionics.

*Table 7-2.* VHF TRANSCEIVER COSTS, HIGH-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Divider Board | 4 | 338 | 342 |
| Converter Board (2 each) | 1 | 23 | 48 |
| Preselector | 9 | 181 | 190 |
| IF Amplifier | 4 | 64 | 68 |
| AGC Board | 3 | 73 | 76 |
| IF Filter-Coupler | 1 | 12 | 13 |
| Attenuator | 7 | 67 | 74 |
| Transmitter/Modulator Power Supply | 42 | 452 | 494 |
| Audio Board | 7 | 154 | 161 |
| VCO | 3 | 28 | 31 |
| Chassis | 9 | 803 | 812 |
| Test and Integration | 3 | 188 | 191 |
| Factory Sell Price | | | 2500 |
| Distributor Markup | | | 750 |
| List Price | | | 3250 |

### 7.2.2 Data Modem

The data modem selected for evaluation is an adaptation of the modem developed in Reference 4. The unit is designed to ARINC specifications for air carrier class equipment and contains all the electronics required for processing baseband signals received from the VHF receiver or for modulating the VHF transmitter. The modem requires external inputs from the aircraft's 4096 coded transponder control for processing of the unique address inherent in a selective data link. The output of the modem provides alphanumeric words for display at the pilot's ATC indicators or digitized data for display on separation-assurance indicators, depending on the address designation contained in the data message.

Table 7-3 presents the physical and economic descriptors of the seven subassemblies comprising the modem. Weights and volumes were estimated by comparison of component types and quantities with existing printed circuit cards used in avionics products. Manufacturing complexities were extracted from the data bank compiled on various subassemblies of specific manufacturers. The remaining parametric data are consistent with the philosophy and economic descriptors used on other avionics cost estimates presented in this study.

*Table 7-3.* PARAMETER VALUES FOR DATA MODEM, HIGH-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values | | | | | |
|---|---|---|---|---|---|---|
| | Modulator/Demodulator | 4096 Code Processor | Logic Decoder (2 ea) | Encoder | Power Supply-Clocks | Enclosure |
| SYSTEM | 3000 | 3000 | 6000 | 3000 | 3000 | 3000 |
| WT | .471 | .451 | .951 | .571 | 1.00 | 4.91 |
| VOL | .01 | .013 | .023 | .014 | .025 | .124 |
| WS | 0 | 0 | 0 | 0 | 0 | 4.91 |
| MCPLXS | - | - | - | - | - | 5.871 |
| NEWST | - | - | - | - | - | .3 |
| MCPLXE | 7.267 | 7.709 | 7.674 | 7.674 | 7.485 | - |
| NEWEL | 1.0 | .2 | 1.0 | 1.0 | .5 | - |
| CMPNTS | 40 | 60 | 75 | 45 | 80 | - |
| ECMPLX | 1.0 | .4 | 1.0 | 1.0 | .4 | .4 |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .865 |
| ECNE | .005 | .001 | .01 | .01 | .005 | - |
| ECNS | - | - | - | - | - | .005 |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 |
| PROJCT | .5 | .5 | .5 | .5 | .5 | .5 |
| DATA | .5 | .5 | .5 | .5 | .5 | .5 |
| TLGTST | .3 | .3 | .3 | .3 | .3 | .3 |
| PLTFM | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | .3 |
| PPROJ | .5 | .5 | .5 | .5 | .5 | .5 |
| PDATA | .5 | .5 | .5 | .5 | .5 | .5 |
| PTLGTS | .3 | .3 | .3 | .3 | .3 | .3 |

Table 7-4 presents the development and production costs for each module of the modem and the expected selling price to air carriers and distributors. The list price of $3699 includes the markup for distribution.

*Table 7-4.* ATC MODEM COSTS, HIGH-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Modulator/Demodulator | 20 | 193 | 213 |
| 4096 Code Process | 18 | 269 | 287 |
| Logic Decode (2 each) | 15 | 446 | 922 |
| Encoder | 23 | 327 | 350 |
| Power Supply/Clocks | 8 | 441 | 449 |
| Enclosure | 3 | 379 | 382 |
| Test and Integration | 3 | 239 | 242 |
| Factory Sell Price | | | 2845 |
| Distributor Markup | | | 854 |
| List Price | | | 3699 |

### 7.2.3 Controls and Indicators

Two types of indicators and one auto-tune control are required to complement the avionics described for the three concepts presented for a VHF data link. The ATC display developed as part of the DABS concept and described in Reference 3 is a standard size ATI-5 panel-mounted instrument designed to ARINC specifications. The display contains the necessary logic processing and lamp driver electronics to convert the digital-data-stream output of a modem into visible ASCII character display. The second required indicator (also described in Reference 3) is the IPC/PWI display developed as part of the separation-assurance enhancement of DABS (also described in Reference 3). The indicator is also housed in an ATI-5 panel-mounted package and contains the logic processing and display drivers necessary to convert the modem output data into the 36 advisory lights of the PWI display and the nine command lights of IPC.

Since the functions of both indicators are similar to that proposed for the DABS concepts, the logic developed under the concept is adaptable to the requirements of a VHF data link, except for the clock rates of the data stream. The physical and economic descriptors shown in Table 7-5 describe the indicators identified in the DABS concept. The auto-tune control required for switching an airborne VHF transceiver to the guard frequencies for IPC/PWI commands and advisories is a device that accepts properly coded digital data from the modem and converts the information into an appropriate two-out-of-five control code for retuning of the transceiver. The unit, designed for airborne application, contains the logic and switching networks necessary for interface between a transceiver and its remote control and the initiating data modem.

Table 7-5. PARAMETER VALUES FOR DISPLAYS AND CONTROL, HIGH-PERFORMANCE AIRCRAFT

| Parameter | ATC Display | IPC/PWI Display | Auto-Tune Control |
|---|---|---|---|
| QTY | 3000 | 3000 | 3000 |
| WT | 2.708 | 6.36 | 2.309 |
| VOL | .059 | .130 | .0648 |
| WS | 1.9 | 3.38 | 1.981 |
| MCPLXS | 6.639 | 5.949 | 5.022 |
| NEWST | .3 | .3 | .2 |
| MCPLXE | 8.706 | 7.948 | 7.709 |
| NEWEL | .8 | .8 | .3 |
| CMPNTS | 64 | 258 | 120 |
| ECMPLX | .9 | .9 | .9 |
| PRMTH | 36 | 36 | 36 |
| LCURVE | .865 | .865 | .865 |
| ECNE | .01 | .005 | .005 |
| ECNS | .005 | .005 | .005 |
| YEAR | 1976 | 1976 | 1976 |
| ESC | 0 | 0 | 0 |
| PROJCT | .5 | .5 | .5 |
| DATA | .5 | .5 | .5 |
| TLGTST | .3 | .3 | .3 |
| PLTFM | 1.7 | 1.7 | 1.7 |
| SYSTEM | .3 | .3 | .3 |
| PPROJ | .5 | .5 | .5 |
| PDATA | .5 | .5 | .5 |
| PTLGTS | .3 | .3 | .3 |

Table 7-5 presents the parametric data required by the pricing model for all three equipments described. Each equipment is treated as a system rather than by subassemblies since the units are normally packaged in nonmodular configurations. The weights and volumes shown are best estimates of probable weight based on component count and packaging densities and average volume of a standard indicator of the size chosen as published in ARINC Characteristics. New structural design is limited to front bezel detailing and nominal chassis configuration since the remainder of the unit is totally controlled by ARINC designs.

Table 7-6 summarizes the pricing model output for the three units evaluated. The factory selling price is based on the manufacturing complexities involved in producing equipment in quantities comparable to those on which the data were developed.

*Table 7-6.* DISPLAY AND CONTROL EQUIPMENT COSTS, HIGH-PERFORMANCE AIRCRAFT

| Equipment | Cost Categories | | | | |
|---|---|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Factory Sell Price (Dollars) | Distributor Mark-Up (Dollars) | List Price (Dollars) |
| ATC Display | 57 | 1519 | 1576 | 473 | 2049 |
| IPC/PWI Display | 90 | 2108 | 2198 | 659 | 2857 |
| Auto-Tune Control | 5 | 294 | 299 | 90 | 389 |

## 7.3 AVIONICS COST DEVELOPMENT, LOW-PERFORMANCE AIRCRAFT

The equipment required by the general-aviation community of low-performance aircraft in support of the VHF concepts is functionally identical to that described in this chapter for the high-performance aircraft. However, the general-aviation practice of packaging systems in light metal enclosures unrestricted by form-fit-function specifications, in combination with the less stringent environmental requirements imposed on general-aviation avionics, allows design and production of avionic equipments which, although performing similar functions, are usually priced considerably lower than air carrier versions. This section presents the cost developement of the general-aviation avionics designed to perform the functions identified for high-performance aircraft but manufactured to the standards of the general-aviation community.

### 7.3.1 VHF Transceiver

The transceiver evaluated is a standard item of avionics available from a leading general-aviation manufacturer. It is designed for panel mounting in the flight console of an aircraft and contains all the necessary controls for operation of the unit. The transceiver provides selection of any of 720 available frequencies in the ATC VHF communications band. The receiver has a usable bandwidth of 22 KHz at the 6 dB points and, although not designed for data reception, can be modified to operate in either the narrow-band or

wide-band mode. The transmitter develops 8 watts at the antenna input and is rated for a 20 percent duty cycle. The transceiver consists of four major subassemblies and the aircraft equipment mounting tray, all of which are produced by the manufacturer. Table 7-7 presents the physical and economic descriptors of the subassemblies reflecting the parametric categorization of a general-aviation manufacturer. The mounting tray is a common item and is treated by the model as a production item only, requiring no new design with zero learning.

*Table 7-7.* PARAMETER VALUES FOR VHF TRANSCEIVER, LOW-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Synthesizer | Transmitter/Modulator | Receiver | Front End Assembly | Mounting Tray | | | | | |
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | | | | | |
| WT | .325 | 1.5 | .219 | 1.2 | .62 | | | | | |
| VOL | .0075 | .0155 | .0072 | .0127 | .07 | | | | | |
| WS | 0 | 0 | 0 | 1.2 | .62 | | | | | |
| MCPLXS | - | - | - | 5.603 | 2.1 | | | | | |
| NEWST | - | - | - | .3 | 0 | | | | | |
| MCPLXE | 7.238 | 6.059 | 7.136 | - | - | | | | | |
| NEWEL | .3 | .3 | .3 | - | - | | | | | |
| CMPNTS | 159 | 20 | 125 | - | - | | | | | |
| ECMPLX | .4 | .4 | .4 | .4 | .3 | | | | | |
| PRMTH | 36 | 36 | 36 | 36 | 36 | | | | | |
| LCURVE | .865 | .865 | .865 | .865 | .95 | | | | | |
| ECNE | .01 | .01 | .01 | - | - | | | | | |
| ECNS | - | - | - | .01 | 0 | | | | | |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | | | | | |
| ESC | 0 | 0 | 0 | 0 | 0 | | | | | |
| PROJCT | .3 | .3 | .3 | .3 | .3 | | | | | |
| DATA | .3 | .3 | .3 | .3 | .3 | | | | | |
| TLGTST | .2 | .2 | .2 | .2 | .2 | | | | | |
| PLTFM | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | | | | | |
| SYSYEM | .3 | .3 | .3 | .3 | .3 | | | | | |
| PPROJ | .3 | .3 | .3 | .3 | .3 | | | | | |
| PDATA | .3 | .3 | .3 | .3 | .3 | | | | | |
| PTLGTS | .2 | .2 | .2 | .2 | .2 | | | | | |

Table 7-8 presents the results of the pricing model evaluation. The factory selling price of $627 is marked up 100 percent for distribution, resulting in the aircraft owner's net price of $1254. This calculated value compares favorably with the manufacturer's published price of $1195 for the transceiver evaluated.

*Table 7-8. VHF TRANSCEIVER, LOW-PERFORMANCE AIRCRAFT*

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Synthesizer | 2 | 156 | 158 |
| Transmitter-Modulator | 5 | 200 | 205 |
| Receiver | 2 | 102 | 104 |
| Front End Enclosure Assembly | 1 | 108 | 109 |
| Mounting Tray | - | 7 | 7 |
| Test and Integration | - | 44 | 44 |
| Factory Sell Price | | | 627 |
| Distributor Markup | | | 627 |
| List Price | | | 1254 |

### 7.3.2 Data Modem

The data modem required by the general-aviation aircraft performs the same function as the air carrier counterpart described in Section 7.2 but utilizes the less stringent packaging and environmental requirements common to general-aviation manufacturing. Table 7-9 describes the general-aviation data modem in the input format of the pricing model. All subassemblies except the enclosure have the same weight and volume specifications as the air carrier modem. The variations in manufacturing and component quality, which result in lower unit costs, are described by the manufacturing complexities, platform, and economic parameters describing the general-aviation manufacturer. Table 7-10 presents the results of the pricing model evaluation. The lower development costs, when compared with those of the air carrier data modem, reflect the lower labor rates and overhead of general-aviation manufacturers, rather than the degree of effort required in designing equipments of similar function.

### 7.3.3 Indicators

The indicators required in support of the VHF data link options for the general-aviation community perform the same function as their air carrier counterparts. Therefore, the designs of the ATC Display and the IPC/PWI Display are identical to those developed in Section 7.2. However, the environmental requirements of general-aviation equipment permit component selection that is considerably less expensive than that required for air carrier avionics. The physical and economic parameters shown in Table 7-11 for the two indicators evaluated reflect the general-aviation manufacturers' producibility of avionics at a considerably lower cost than the air carrier avionics, although

| Parameter | Modulator/Demodulator | 4096 Code Processor | Decoder (2 ea) | Encoder | Power Supply/Clocks | Enclosure | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| QTY | 300 | 3000 | 6000 | 3000 | 3000 | 3000 | | | | |
| WT | .471 | .451 | .951 | .571 | 1.0 | 1.357 | | | | |
| VOL | .013 | .013 | .023 | .014 | .025 | .064 | | | | |
| WS | 0 | 0 | 0 | 0 | 0 | 1.375 | | | | |
| MCPLXS | - | - | - | - | - | 2.905 | | | | |
| NEWST | - | - | - | - | - | .2 | | | | |
| MCPLXE | 5.639 | 5.621 | 5.911 | 5.911 | 4.326 | - | | | | |
| NEWEL | .8 | .2 | .8 | .8 | .5 | - | | | | |
| CMPNTS | 40 | 60 | 75 | 45 | 40 | - | | | | |
| ECMPLX | .9 | .4 | .9 | .9 | .4 | .4 | | | | |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 | | | | |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .9 | | | | |
| ECNE | .005 | .005 | .01 | .01 | .005 | - | | | | |
| ECNS | - | - | - | - | - | .005 | | | | |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | | | | |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| PROJCT | .3 | .3 | .3 | .3 | .3 | .3 | | | | |
| DATA | .3 | .3 | .3 | .3 | .3 | .3 | | | | |
| TLGTST | .2 | .2 | .2 | .2 | .2 | .2 | | | | |
| PLTFM | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | | | | |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | .3 | | | | |
| PPROJ | .3 | .3 | .3 | .3 | .3 | .3 | | | | |
| PDATA | .3 | .3 | .3 | .3 | .3 | .3 | | | | |
| PTLGTS | .2 | .2 | .2 | .2 | .2 | .2 | | | | |

*Table 7-9.* PARAMETER VALUES FOR DATA MODEM, LOW-PERFORMANCE AIRCRAFT

(Column group heading: Parameter Values)

*Table 7-10.* ATC MODEM COSTS, LOW-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Modulator/Demodulator | 14 | 55 | 69 |
| 4096 Code Processor | 2 | 54 | 56 |
| Logic Decoder (2 each) | 11 | 109 | 240 |
| Encoder | 16 | 82 | 98 |
| Power Supply and Clocks | 5 | 32 | 37 |
| Enclosure | 1 | 16 | 17 |
| Test and Integration | 2 | 86 | 88 |
| Factory Sell Price | | | 605 |
| Distributor Markup | | | 605 |
| List Price | | | 1210 |

*Table 7-11.* PARAMETER VALUES FOR DISPLAYS, LOW-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values: ATC Display | | IPC/PWI Display | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| QTY | 3000 | | 3000 | | | | | | | |
| WT | 2.708 | | 5.36 | | | | | | | |
| VOL | .059 | | .13 | | | | | | | |
| WS | 1.9 | | 2.38 | | | | | | | |
| MCPLXS | 4.729 | | 4.729 | | | | | | | |
| NEWST | .3 | | .3 | | | | | | | |
| MCPLXE | 6.212 | | 6.212 | | | | | | | |
| NEWEL | .8 | | .8 | | | | | | | |
| CMPNTS | 64 | | 258 | | | | | | | |
| ECMPLX | .9 | | .9 | | | | | | | |
| PRMTH | 36 | | 36 | | | | | | | |
| LCURVE | .865 | | .865 | | | | | | | |
| ECNE | .005 | | .005 | | | | | | | |
| ECNS | .005 | | .005 | | | | | | | |
| YEAR | 1976 | | 1976 | | | | | | | |
| ESC | 0 | | 0 | | | | | | | |
| PROJCT | .5 | | .5 | | | | | | | |
| DATA | .5 | | .5 | | | | | | | |
| TLGTST | .2 | | .2 | | | | | | | |
| PLTFM | 1.6 | | 1.6 | | | | | | | |
| SYSTEM | .3 | | .3 | | | | | | | |
| PPROJ | .3 | | .3 | | | | | | | |
| PDATA | .3 | | .3 | | | | | | | |
| PTLGTS | .2 | .2 | .2 | | | | | | | |

performing the same function. Table 7-12 presents the PRICE-developed cost of the indicators applicable to the general-aviation users. The IPC/PWI display reflects the large quantity of discrete logic required to perform the functions of separation assurance and traffic advisories. If justified by user demand, this logic would probably be integrated into LSIs, resulting in higher development costs but lower cost of avionics.

*Table 7-12.* DISPLAY EQUIPMENT COSTS, LOW-PERFORMANCE AIRCRAFT

| Equipment | Cost Categories | | | | |
|---|---|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Factory Sell Price (Dollars) | Distributor Mark-Up (Dollars) | List Price (Dollars) |
| ATC Display | 25 | 218 | 243 | 243 | 486 |
| IPC/PWI Display | 45 | 512 | 557 | 557 | 1114 |

The control unit necessary for the "Extended VHF Data Link" option of the MITRE study has not been developed for the general-aviation users, since general-aviation avionics are usually packaged in single enclosures with integral controls and are not suitable for adaptation of intermediate controls. The auto-tune control function could be incorporated in the basic VHF transceiver as a model revision by the manufacturer at a nominal increase in transceiver cost.

## 7.4 SUMMARY

The cost of avionics required for implementing each of the three options proposed by MITRE/METREK is presented in Table 7-13. Unit avionics costs are shown rather than totals because of the various combinations possible for the options and the aircraft configurations. For a single system installation of the basic VHF voice-only system, the minimum equipment required would consist of the transceiver, remote control, and antenna, for a total avionics cost of $3196 to an air carrier. The costs of controls and antennas used in this study were obtained from manufacturers' price lists applicable to the users of interest.

| *Table 7-13.* VHF DATA LINK AVIONICS COSTS | | | |
|---|---|---|---|
| | Cost (in dollars) by Aircraft Category | | |
| Equipment | Air Carriers | High-Performance General Aviation | Low-Performance General Aviation |
| VHF Transceiver | 2500 | 3250 | 1254 |
| Data Link Modem | 2845 | 3699 | 1240 |
| ATC Display | 1576 | 2049 | 486 |
| IPC Display | 2198 | 2857 | 1114 |
| Controls (VHF) | 516* | 516* | N/A |
| Control (Auto-Tune) | 299 | 389 | N/A |
| Antenna | 180* | 240* | 16* |

*Information from manufacturers' price lists

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CHAPTER EIGHT

# AIRBORNE COLLISION AVOIDANCE SYSTEM

The airborne collision avoidance system (ACAS) concept was introduced as a candidate for separation assurance in the early 1970s and was extensively evaluated by the FAA for both technical capability and the economic impact of system implementation. Originally, three concepts were proposed: the Honeywell AVOIDS, the McDonnell Douglas EROS, and the RCA Secant systems. All three concepts were proposed for operation in the L-Band portion of the frequency spectrum with a center frequency of 1605 MHz. The FAA evaluation resulted in a recommendation that the Honeywell AVOIDS be chosen as the ACAS candidate for separation assurance. This chapter addresses the development of the avionics costs associated with the Honeywell AVOIDS concept for both the air carrier and general-aviation classes of equipments. The equipment designs and physical descriptions used in this analysis are those developed in the ARINC Research study (Reference 2) supporting the FAA evaluation of the ACAS concepts.

## 8.1 AVIONICS COST DEVELOPMENT, HIGH-PERFORMANCE AIRCRAFT

The electronics package recommended by Honeywell as a production configuration of the AVOIDS-I high-performance avionics is designed to ARINC specifications for a 3/8-ATR short enclosure containing the RF, IF, and digital processor modules necessary for operation of the system. The transmitter is similar to an ATCRBS cavity oscillator operating at 1605 MHz with a pulse power output of 1000 watts at a low duty cycle. The receiver module contains dual (diversity) RF and IF stages connected to each of two antenna ports at the receiver input. Five digital processor modules provide all the logic-processing and code-converting functions necessary for interrogation and decoding operation of the system. A power supply module and the chassis and enclosure make up the remainder of electronics package. All assemblies, other than the cavity oscillator and RF head, are expected to be produced by the avionics manufacturer. The two exceptions will probably be purchased from a specialty manufacturer and are so treated by the pricing model.

Table 8-1 presents the physical and economic descriptors associated with the nine subassemblies of AVOIDS-I. The five logic cards are considered identical in the language of the pricing model and therefore are presented only once. However, since each card requires unique design and development, the model was exercised separately for each card to identify the development costs associated with the logic portion of the electronics package.

Table 8-1. PARAMETER VALUES FOR AVOIDS I ELECTRONICS, HIGH-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Modulator/High Voltage Power Supply | IF Amplifier | Logic Card (5 ea) | Low Voltage Power Supply | Housing & Chassis | | | | | |
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | | | | | |
| WT | .852 | .547 | .219 | .922 | 3.085 | | | | | |
| VOL | .02 | .0124 | .0076 | .0142 | .21 | | | | | |
| WS | .25 | 0 | 0 | .5 | 3.085 | | | | | |
| MCPLXS | 5.565 | - | - | 5.465 | 7.074 | | | | | |
| NEWST | .7 | - | - | .2 | .7 | | | | | |
| MCPLXE | 7.730 | 8.275 | 7.865 | 7.814 | - | | | | | |
| NEWEL | .7 | .8 | 1.0 | .3 | - | | | | | |
| CMPNTS | 47 | 184 | 20 | 50 | - | | | | | |
| ECMPLX | .4 | .7 | 1.5 | .7 | .4 | | | | | |
| PRMTH | 36 | 36 | 36 | 36 | 36 | | | | | |
| LCURVE | .865 | .865 | .865 | .865 | .865 | | | | | |
| ECNE | .01 | .1 | .1 | .05 | - | | | | | |
| ECNS | .01 | - | - | .05 | .01 | | | | | |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | | | | | |
| ESC | 0 | 0 | 0 | 0 | 0 | | | | | |
| PROJCT | .5 | .5 | .5 | .5 | .5 | | | | | |
| DATA | .5 | .5 | .5 | .5 | .5 | | | | | |
| TLGTST | .3 | .3 | .3 | .3 | .3 | | | | | |
| PLTFM | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | | | | | |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | | | | | |
| PPROJ | .5 | .5 | .5 | .5 | .5 | | | | | |
| PDATA | .5 | .5 | .5 | .5 | .5 | | | | | |
| PTLGTS | .3 | .3 | .3 | .3 | .3 | | | | | |

Table 8-2 presents the output of the pricing model, the manufacturer's quoted price of purchased items, and the expected factory selling price of the avionics to the air carrier industry. The list price includes the expected markup for distribution and is the cost to the individual aircraft owner. The development costs have been amortized over the entire 3000-unit production run. The logic development cost of $216,000 ($72 per unit) appears reasonable for development of the logic functions other than microprocessors, which are off the shelf and not subject to additional development costs.

*Table 8-2.* **HONEYWELL** AVOIDS I CAS COSTS, HIGH-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| **Transmitter-Modulator/High Voltage Power Supply** | 14 | 405 | 419 |
| ***Transmitter Cavity Oscillator** | 0 | 100 | 100 |
| **Receiver/IF Amplifier** | 13 | 580 | 593 |
| **Logic Cards** | 72 | 874 | 946 |
| **Power Supply-Low Voltage** | 9 | 360 | 369 |
| ***RF Head Assembly** | 0 | 587 | 587 |
| **Housing** | 10 | 829 | 839 |
| **Test and Integration** | 5 | 121 | 110 |
| **Factory Sell Price** | | | 3979 |
| **Distributor Markup** | | | 1194 |
| **List Price** | | | 5173 |

***Subcontracted purchased items**

## 8.2 AVIONICS COST DEVELOPMENT, LOW-PERFORMANCE AIRCRAFT

The general-aviation version of the Honeywell CAS design has been identified as AVOIDS-II. Although performing interrogation and processing functions similar to those of the AVOIDS-I, the electronics package for low-performance aircraft is less complex, requiring single receivers, 250-watt transmitter-oscillators, and packaging for installation in the flight console of the aircraft. Logic processing is reduced because of lower operating altitudes and shorter-range gates and tracking. A micropressor similar to the type used in AVOIDS-I is included, but it conforms to the lower environmental requirements common to the general-aviation community. The command indicator necessary for system operation is built into the electronic package, requiring only the addition of two antennas for system operation.

The six subassemblies constituting the AVOIDS-II electronics package are described in Table 8-3, except for the cavity oscillator, which is an item purchased by the avionics manufacturer. The parameters shown in the table reflect general-aviation manufacturer data developed and stored in ARINC Research files. The physical descriptors are based on detailed information provided by Honeywell in support of the ARINC Research study of ACAS alternatives. The engineering complexities shown for the logic cards indicate a difficult new design, consistent with the requirement for either LSI development or dense integration of microprocessors and discrete logic components.

*Table 8-3.* PARAMETER VALUES FOR AVOIDS II ELECTRONICS, LOW-PERFORMANCE AIRCRAFT

| Parameter | Receiver | Logic Card No. 1 | Logic Card No. 2 | Power Supply | Chassis & Enclosure | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | | | | | |
| WT | .38 | .631 | .631 | .188 | .746 | | | | | |
| VOL | .0068 | .0228 | .0228 | .0029 | .091 | | | | | |
| WS | .1 | 0 | 0 | 0 | .745 | | | | | |
| MCPLXS | 3.932 | - | - | - | 4.270 | | | | | |
| NEWST | .2 | - | - | - | .5 | | | | | |
| MCPLXE | 6.037 | 6.307 | 6.307 | 5.714 | - | | | | | |
| NEWEL | .5 | 1.0 | 1.0 | .3 | - | | | | | |
| CMPNTS | 114 | 29 | 28 | 51 | - | | | | | |
| ECMPLX | .4 | 1.5 | 1.5 | .4 | .4 | | | | | |
| PRMTH | 36 | 36 | 36 | 36 | 36 | | | | | |
| LCURVE | .865 | .865 | .865 | .865 | .865 | | | | | |
| ECNE | .03 | .05 | .05 | .03 | - | | | | | |
| ECNS | .03 | - | - | - | .03 | | | | | |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | | | | | |
| ESC | 0 | 0 | 0 | 0 | 0 | | | | | |
| PROJCT | .5 | .5 | .5 | .5 | .5 | | | | | |
| DATA | .5 | .5 | .5 | .5 | .5 | | | | | |
| TLGTST | .2 | .2 | .2 | .2 | .2 | | | | | |
| PLTFM | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | | | | | |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | | | | | |
| PPROJ | .3 | .3 | .3 | .3 | .3 | | | | | |
| PDATA | .3 | .3 | .3 | .3 | .3 | | | | | |
| PTLCTS | .2 | .2 | .2 | .2 | .2 | | | | | |

Parameter Values (column group heading)

The remainder of the subassemblies are considered routine, second-generation products requiring nominal design to adapt to the ACAS configuration.

Table 8-4 presents the results of exercising the pricing model. The factory selling price of $559 and the marked up list price of $1118 compare favorably with the predicted cost of the AVOIDS-II developed in Reference 2.

*Table 8-4.* HONEYWELL AVOIDS II CAS COSTS, LOW-PERFORMANCE AIRCRAFT

| Equipment | Cost Factors | | |
|---|---|---|---|
| | Development (Dollars/Unit) | Production (Dollars/Unit) | Total (Dollars) |
| Receiver | 5 | 57 | 62 |
| Transmitter | 0 | 55 | 55 |
| Logic No. 1 | 37 | 135 | 172 |
| Logic No. 2 | 37 | 135 | 172 |
| Power Supply | 2 | 29 | 31 |
| Chassis | 1 | 25 | 26 |
| Test and Evaluation | 2 | 39 | 41 |
| Factory Sell Price | | | 559 |
| Distributor Markup | | | 559 |
| List Price | | | 1118 |

## 8.3 SUMMARY

The implementation of ACAS in air carrier and other high-performance aircraft requires an electronics package, command indicator, and two antennas as a minimum, nonredundant installation. Low-performance aircraft CAS avionics have the indicator built into the electronics package because of its proposed cockpit panel location. Table 8-5 presents the component and cumulative costs of equipment necessary for a single system implementation in the three user communities of interest. The cost of the command indicator and antennas is taken from manufacturers' quotations and published price lists.

*Table 8-5.* ACAS AVIONICS COSTS (SINGLE SYSTEM PER AIRCRAFT)

| Equipment | Cost (in dollars) by Aircraft Category | | |
|---|---|---|---|
| | Air Carrier | High-Performance General Aviation | Low-Performance General Aviation |
| ACAS Electronics | 3979 | 5173 | 1118 |
| Command Indicator* | 1092 | 1092 | N/A |
| Antennas (2 each)* | 126 | 150 | 26 |
| Total Cost | 5197 | 6415 | 1144 |

*Prices from manufacturers' quotes and published price lists

# CHAPTER NINE

# RESULTS OF EVALUATIONS

The study has developed costs of avionics based on a uniform approach of cost estimating with the assistance of a pricing model. Costs were developed for existing systems (whose advertised prices are available for comparison with the study results) to give credibility to the concept and the parametric data used in exercising the pricing model. The data describing existing systems were developed through detailed weight and volume measurements, and extensive sensitivity analyses. The data base compiled on many systems of several leading avionics manufacturers producing either high-performance aircraft equipment or low-performance aircraft equipment was then used in preparing the physical and economic descriptors for new-system evaluation by the pricing model. This chapter summarizes the results of the evaluation and presents the parametric data developed by this study in a system configuration.

## 9.1 *PARAMETRIC DATA OF SYSTEMS EVALUATED*

The majority of the systems evaluated were estimated at a subassembly level, and the subassemblies were then integrated into the system configuration. The systems can also be defined by a single set of physical and economic descriptors that will result in similar cost outputs from the pricing model. However, more precise input data are required than those for subassemblies, and there are fewer systems of similar functional design and complexity from any single manufacturer on which a credible data base can be established. Tables 9-1 and 9-2 present the system parametric data equivalent to the subassembly data developed in the study for the high-performance and low-performance aircraft avionics, respectively. These tables permit comparison of the parametric data, in summary form, between all the systems evaluated. Close inspection of the data (e.g., ATCRBS and DABS) shows that the DABS transponder, although more complex and more difficult to produce, has a lower requirement for new structual and electronic design and is described as having lower engineering complexity than ATCRBS. This result is justified on the basis of the study assumption that in developing a DABS transponder, the manufacturer would use either entire modules or a high percentage of the design of the modules developed for ATCRBS. The ATCRBS transponder, however, is the first generation of radar beacon avionics and requires almost totally new design. This type of approach was used commonly throughout the study to reflect the expected development and production methods of the avionics manufacturers.

Table 9-1. SYSTEM PHYSICAL AND ECONOMIC DESCRIPTORS, HIGH-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ATCRBS Transponder | DABS/Transponder | SAB | VHF Transceiver | VHF Data Link Modem | ATC Display | IPC Display | ACAS | | Units |
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | | ea |
| WT | 8.9 | 13.45 | 13.03 | 13.0 | 9.30 | 2.71 | 6.36 | 7.98 | | lbs |
| VOL | .228 | .308 | .228 | .212 | .124 | .059 | .130 | .21 | | cv.ft |
| WS | 6.382 | 10.06 | 9.61 | 9.279 | 4.91 | 1.9 | 3.38 | 5.065 | | lbs |
| MCPLXS | 7.393 | 6.234 | 6.235 | 6.154 | 5.871 | 6.639 | 5.949 | 6.958 | | - |
| NEWST | .41 | .27 | .1 | .50 | .3 | .3 | .3 | .525 | | % |
| MCPLXE | 8.561 | 8.607 | 8.461 | 7.494 | 7.797 | 8.706 | 7.948 | 8.138 | | - |
| NEWEL | .61 | .32 | .11 | .77 | .81 | .8 | .8 | .833 | | % |
| CMPNTS | 667 | 1350 | 1198 | 844 | 375 | 64 | 258 | 453 | | ea |
| ECMPLX | .733 | .5 | .413 | .873 | .59 | .9 | .9 | 1.04 | | - |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | | mos |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | | % |
| ECNE | .01 | .01 | .005 | .01 | .01 | .005 | .005 | .07 | | % |
| ECNS | .01 | .01 | .005 | .01 | .01 | .005 | .005 | .01 | | % |
| YEAR | 1975 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | | Yr |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | % |
| PROJCT | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | | % |
| DATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | | % |
| TLGTST | .3 | .3 | .3 | .3 | .5 | .3 | .3 | .3 | | % |
| PLTFM | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | | - |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | | % |
| PPROJ | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | | % |
| PDATA | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | | % |
| PTLGTS | .3 | .3 | .3 | .3 | .5 | .3 | .3 | .3 | | |

*Table 9-2.* SYSTEM PHYSICAL AND ECONOMIC DESCRIPTORS, LOW-PERFORMANCE AIRCRAFT

| Parameter | Parameter Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ATCRBS Transponder | DABS Transponder | SAB Transponder | VHF Transceiver | VHF Data Link Modem | ATC Display | IPC Display | ACAS Electronics | | Units |
| QTY | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | | ea |
| WT | 2.8 | 3.1 | 346 | 3.25 | 4.82 | 2.71 | 5.36 | 2.88 | | lbs |
| VOL | .08 | 0.1 | .091 | .07 | .064 | .059 | .13 | .09 | | cu.ft. |
| WS | 1.9 | 1.4 | 2.30 | 1.2 | 1.375 | 1.9 | 2.38 | .845 | | lbs |
| MCPLXS | 4.458 | 5.182 | 4.454 | 5.603 | 2.905 | 4.729 | 4.729 | 4.360 | | - |
| NEWST | .45 | .3 | .13 | .3 | .2 | .3 | .3 | .4 | | % |
| MCPLXE | 6.323 | 7.043 | 6.421 | 6.680 | 5.851 | 6.212 | 6.212 | 6.427 | | - |
| NEWEL | .7 | .42 | .42 | .3 | .63 | .8 | .8 | .77 | | % |
| CMPNTS | 213 | 398 | 238 | 304 | 260 | 64 | 258 | 222 | | ea |
| ECMPLX | .57 | .52 | .51 | .4 | .61 | .9 | .9 | .84 | | - |
| PRMTH | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | | mos |
| LCURVE | .865 | .865 | .865 | .865 | .865 | .865 | .865 | .865 | | % |
| ECNE | .032 | .01 | .01 | .01 | .01 | .005 | .005 | .04 | | % |
| ECNS | .008 | .01 | .01 | .01 | .005 | .005 | .005 | .03 | | % |
| YEAR | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | 1976 | | Yr |
| ESC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | % |
| PROJCT | .5 | .5 | .5 | .3 | .3 | .5 | .5 | .5 | | % |
| DATA | .5 | .5 | .5 | .3 | .3 | .5 | .5 | .5 | | % |
| TLGTST | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | | % |
| PLTFM | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | | - |
| SYSTEM | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | | % |
| PPROJ | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | | % |
| PDATA | .3 | .3 | .3 | .3 | .3 | .3 | .3 | .3 | | % |
| PTLGTS | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | | % |

## 9.2 COST DATA OF SYSTEMS EVALUATED

The avionics costs developed by application of the pricing model are summarized in Table 9-3. The values indicate the probable selling price of each item of avionics to the air carriers and to the high-performance general-aviation and low-performance general-aviation users. Appropriate markups for distribution have been included on the basis of known or expected practices of the avionics manufacturers. All costs are based on the 1976 dollar without inflation. Potential variability in costs exists as a function of the production volume dictated by user demand. However, comparison of avionics cost based on the data presented is possible since each concept was evaluated with a uniform production quantity.

*Table 9-3* ACQUISITION COST OF AVIONICS

| Equipment | Cost (in dollars) by User Category | | |
|---|---|---|---|
| | Air Carrier | High-Performance General Aviation | Low-Performance General Aviation |
| ATCRBS Transponder | 3975 | 5169 | 612 |
| DABS Transponder | 5212 | 6776 | 1352 |
| SAB Transponder | 4176 | 5429 | 784 |
| VHF Transceiver | 2500 | 3250 | 1254 |
| VHF Data Modem | 2845 | 3699 | 1240 |
| ATC Display | 1576 | 2049 | 486 |
| IPC/PWI Display | 2198 | 2857 | 1114 |
| Auto-Tune Control | 299 | 389 | N/A |
| ACAS Electronics | 3979 | 5173 | 1118 |

All systems evaluated in this study require additional equipment for implementation. Antennas, controls, and displays complement the basic avionics package and provide the necessary configuration for system operation in the airborne environment. Table 9-4 presents the expected cost of acquisition of a complete system for a single, nonredundant implementation in an aircraft of the three user categories identified. Costs of the complementaty equipment were either developed as documented in this study or taken from manufacturers' price lists for the appropriate user communities. The system costs shown in the table provide a convenient summary of information contained in the study and are intended for comparison of the implementation costs of the alternatives for the next generation of ATC systems.

Table 9-4. ACQUISITION COST OF SYSTEMS - SINGLE SYSTEM PER AIRCRAFT

| System | Cost (in dollars) by User Category | | |
|---|---|---|---|
| | Air Carrier | High-Performance General Aviation | Low-Performance General Aviation |
| ATCRBS | 4554 | 5760 | 625 |
| DABS/IPC | 8052 | 10299 | 1365 |
| SAB | 4755 | 6020 | 797 |
| VHF Voice | 3196 | 4006 | 1270 |
| VHF Data Link | 4772 | 6055 | 1756 |
| VHF D/L + IPC | 7269 | 9301 | 2870 |
| ACAS | 5197 | 6415 | 1144 |

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*APPENDIX A*

RCA PRICE MODEL INPUT PARAMETERS

The appendix presents a listing of the input parameters used by the RCA PRICE model. Figure A-1 shows a typical input worksheet; Figure A-2 shows an example of a typical model output data sheet.

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PRICE System
Input Worksheet

RCA Government and Commercial Systems

| Item | | | | Date | |
|---|---|---|---|---|---|
| | DECODER-DATA MODEM-CA | | | | |

| | | | | | |
|---|---|---|---|---|---|
| General | QTY | PROTOS | WT | VOL | MODE |
| | 3000 | 1 | .951 | .023 | 1 |
| | QTYSYS | INTEGE | INTEGS | AMULTE (%) | AMULTM (%) |
| | 1 | .7 | .3 | 138000 | 138000 |
| Mechanical/ Structural | WS | MCPLXS | PRODS | NEWST | DESRPS |
| | .001 | 0 | 4.2 | 0 | 0 |
| Electronics | USEVOL | MCPLXE | PRODE | NEWEL | DESRPE |
| | .99 | 7.674 | 0 | 1.0 | 2 |
| | PWR | CMPNTS | CMPID | PWRFAC | CMPEFF |
| | 0 | 75 | 0 | 1.6 | 0 |
| Engineering | ENMTHS | ENMTHP | ENMTHT | ECMPLX | PRNF |
| | 1 | 10 | 10 | 1.0 | 0 |
| Production | PRMTHS | PRMTHF | LCURVE | ECNE | ECNS |
| | 12 | 48 | .865 | .01 | 0 |
| Purchased Item (Mode 3) | WS | BVCOST | LCURVE | | |
| GFE (Mode 4) | WS | MCPLXE | MCPLXS | | |
| Additional Data (Modes 9 & 10) | MCONST | MEXP | WECF | TARCST (Mode [illegible]) | |
| Global | YEAR | ESC | PROJCT | DATA | TLGTST |
| | 1976 | 0 | .5 | .5 | .3 |
| | PLTFM | SYSTEM | PPROJ | PDATA | PTLGTS |
| | 1.7 | .3 | .5 | .5 | .3 |

MODES

0 PRINT TOTALS
1 E/M ITEM
2 MECH ITEM
3 PURCH ITEM
4 GFE ITEM
5 INTEG & TEST
6 MODIFIED PURCH ITEM
7 MODIFIED GFE ITEM
8 [illegible]
9 [illegible] ALCWT & VOL
10 GEOSYN

Notes:

GC 1505 [illegible]

*Figure A-1.* TYPICAL PRICE INPUT WORKSHEET

```
DECODER-DATA MODEM-CA

INPUT DATA

ELECTRONICS
USEVOL   0.990 MCPLXE  7.674 PRODE    0.000 NEWEL     1.000 DESRPE   2.000
PWR      0.000 CMPNTS    75. CMPID    0.000 PWRFAC    1.600 CMPEFF   0.000

ENGINEERING
ENMTHS     1.0 ENMTHP   10.0 ENMTHT    10.0 ECMPLX    1.000 PRNF     0.000

PRODUCTION
PRMTHS    12.0 PRMTHF   48.0 LCURVE   0.865 ECNE      0.010 ECNS     0.000

GLOBAL
YEAR     1976. ESC     0.00% PROJCT   0.500 DATA      0.500 TLGTST   0.300
PLATFM   1.700 SYSTEM  0.300 PPROJ    0.500 PDATA     0.500 PTLGTS    0.30

PROGRAM COST           DEVELOPMENT         PRODUCTION        TOTAL COST
ENGINEERING
 DRAFTING                   35817.               398.            36214.
 DESIGN                    107786.              1178.           108964.
 SYSTEMS                     5303.                 0.             5303.
 PROJ MGMT                   7942.             38882.            46824.
 DATA                        2393.              1617.             4010.
  SUBTOTAL(ENG)            159240.             42075.           201315.

MANUFACTURING
 PRODUCTION                    0.           1450817.          1450817.
 PROTOTYPE                   4091.                0.             4091.
 TOOL-TEST EQ                 281.             51447.            51728.
  SUBTOTAL(MFG)              4372.           1502264.          1506636.

  TOTAL COST               163613.           1544339.          1707951.

VOL       0.023 AVCOST  483.61 TOTAL AV PROD COST  514.78 LCURVE  0.865
WT        0.951 ECNE     0.010 ECNS     0.011 DESRPE-0.014 DESRPS  0.000

MECH/STRUCT
WS        0.001 WSCF     0.043 MECID    0.000 PRODS  4.200 MCPLXS  3.871
ELECTRONICS
WE        0.950 WECF    41 722 CMPID    0.000 PRODE  4.224 MCPLXE  7.674
PWR       1.674 CMPNTS     75.                PWRFAC 1.600 CMPEFF-14.440

SCHEDULES
ENMTHS    1.000 ENMTHP  10.000 ENMTHT 10.000 ECMPLX 1.000 PRNF     0.000
PRMTHS   12.000 PRMTHF  48.000 AVER. PROD RATE PER MONTH          83.333

 OST RANGES            DEVELOPMENT         PRODUCTION        TOTAL COST
     FROM                  147540.           1361420.          1508959.
     CENTER                163613.           1544339.          1707951.
     TO                    187380.           1792384.          1979764.

 )D     =1
```

*Figure A-2.* TYPICAL PRICE OUTPUT SHEET

## APPENDIX B

## REFERENCES

1. WP 11886, *The Cost of Various Alternatives to Improving Communications and Surveillance for Aircraft Separation Services in the National Airspace System,* The MITRE Corporation, METREK Division, October 1976.

2. FAA-EM-76-1, *Cost Analysis of Airborne Collision Avoidance Systems (CAS) Concepts,* ARINC Research Corporation, December 1975.

3. FAA-EM-76-2, *Cost Analysis of the Airborne Portion of the Discrete Address Beacon System Intermittent Positive Control (DABS/IPC) Concept,* ARINC Research Corporation, December 1975.

4. FAA-EM-(Draft), *Investigation of the Technical and Operational Feasibility of Using a VHF Data Link for Transmission of Intermittent Postive Control (IPC),* Draft Report, ARINC Research Corporation, August 1977.

5. FAA-EM-(Draft), *Selective Address Beacon (SAB) System,* Draft Report, ARINC Research Corporation, November 1977.

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